

BBC

ENGINEERING DIVISION

MONOGRAPH

NUMBER 27: JANUARY 1960

The Equipment of the BBC Television Film Studios at Ealing

by

N. F. CHAPMAN

(Planning and Installation Department, BBC Engineering Division)

BRITISH BROADCASTING CORPORATION

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FOREWORD

THIS is one of a series of Engineering Monographs published by the British Broadcasting Corporation. About six are produced every year, each dealing with a technical subject within the field of television and sound broadcasting. Each Monograph describes work that has been done by the Engineering Division of the BBC and includes, where appropriate, a survey of earlier work on the same subject. From time to time the series may include selected reprints of articles by BBC authors that have appeared in technical journals. Papers dealing with general engineering developments in broadcasting may also be included occasionally.

This series should be of interest and value to engineers engaged in the fields of broadcasting and of telecommunications generally.

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2.	<i>Absolute Measurements in Magnetic Recording</i>	SEPTEMBER 1955
3.	<i>The Visibility of Noise in Television</i>	OCTOBER 1955
4.	<i>The Design of a Ribbon Type Pressure-gradient Microphone for Broadcast Transmission</i>	DECEMBER 1955
5.	<i>Reproducing Equipment for Fine-groove Records</i>	FEBRUARY 1956
6.	<i>A V.H.F./U.H.F. Field-strength Recording Receiver using Post-detector Selectivity</i>	APRIL 1956
7.	<i>The Design of a High Quality Commentator's Microphone Insensitive to Ambient Noise</i>	JUNE 1956
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THE EQUIPMENT OF THE BBC TELEVISION FILM STUDIOS AT EALING

SUMMARY

BBC film production facilities for the Television Service are based at the Television Film Studios, Ealing Green, London, W.5.

This monograph describes the operations which are involved and the facilities provided. Descriptions of the technical equipment and areas are included, together with some discussion on the differences between cinema film production methods and television film operations.

1. Introduction

The BBC's Television Film Department, in conjunction with the Television Operations and Maintenance Department, provides all the main film production facilities for the Television Service. These comprise filming, editing, reviewing, dubbing, and film library activities. Up to January 1956 these operations were carried out in miscellaneous areas in the television premises at Alexandra Palace, Riverside, and Lime Grove. The increasing volume of work and the difficulties of filming in television studios resulted in a need for the concentration of facilities and the provision of separate studios for filming purposes. To meet this demand the BBC purchased the Ealing Film Studios premises in December 1955 and moved all its film production to this centre. The centre is in a convenient location within twenty minutes' travelling time of the BBC's new Television Centre at White City.

Present plans are that Ealing will continue as the main film production centre for the Television Service after completion of the White City television headquarters.

2. Terminology

Various standard technical terms in current use in the BBC are used in this monograph and these are explained in the Appendix. Examples are abbreviated terms, e.g. SEPMAg, used to describe the various types of sound film used.

3. General Design of the Centre

The Ealing Film Studios as purchased by the BBC comprised a compact centre basically arranged for cinema feature film production. Whilst many areas could obviously be used largely unaltered, there are considerable differences between feature work and television film operations. It was necessary, therefore, in order to achieve maximum efficiency and to meet programme demands, to replan certain areas and to introduce modifications and additions to the equipment and facilities.

Basically, feature film production for the cinema requires a small number of fairly complicated and lavish facilities whilst television film production requires a very large number of possibly more simple, but nevertheless highly flexible, units. Television film studios can be smaller than those required for feature work, but a considerable increase in editing, review, and dubbing facilities are necessary to handle the greater volume of film.

Ealing provided three studios: Studio 2 measuring

120 ft by 80 ft and 3A and 3B each measuring 70 ft by 90 ft approximately. These have not been modified structurally, apart from roof reinforcements to improve weather-proofing.

Approximately twenty extra cutting rooms have been added, however, together with a suite of six review theatres of comprehensive design. Sound recording facilities have been replanned and, in addition, a highly flexible sound transfer suite has been installed. A film titling room has been provided and a modern block of film vaults has been built to provide additional storage space for the ever-growing film library. Finally a well-equipped area has been constructed for the maintenance of film apparatus.

4. Facilities

Before proceeding with detailed descriptions of the areas and equipment an analysis of the services provided at Television Film Studios will be of value. Film is used in television for the following purposes:

- (a) Documentary material for live television programmes.
- (b) Coverage of news events for news programmes.
- (c) Coverage of sports events for sports programmes.
- (d) Production of complete documentary films for television transmission.
- (e) Pre-filming of 'produced' sequences for television plays or documentary programmes, either on location or in studios.
- (f) Production of film titles, captions, and animated diagrams.
- (g) Telerecording of television programmes.

For reasons of organization, the following activities are not carried out by the Film Department, and are, therefore, excluded from this monograph:

News coverage ((b) above). This activity is the responsibility of the News Department at Alexandra Palace.

Telerecording of television programmes ((g) above).

The technical operation of recording television programmes and also the transmission of all film material are the responsibility of Engineering Division and are carried out mainly at Lime Grove. Film Department, however, handle certain of the programme aspects of telerecording, including any programme checking and editing necessary. This work is carried out both at Ealing and Lime Grove.

The operations at Television Film Studios at Ealing, therefore, embrace those referred to in Sections (a), (c), (d), (e), and (f).

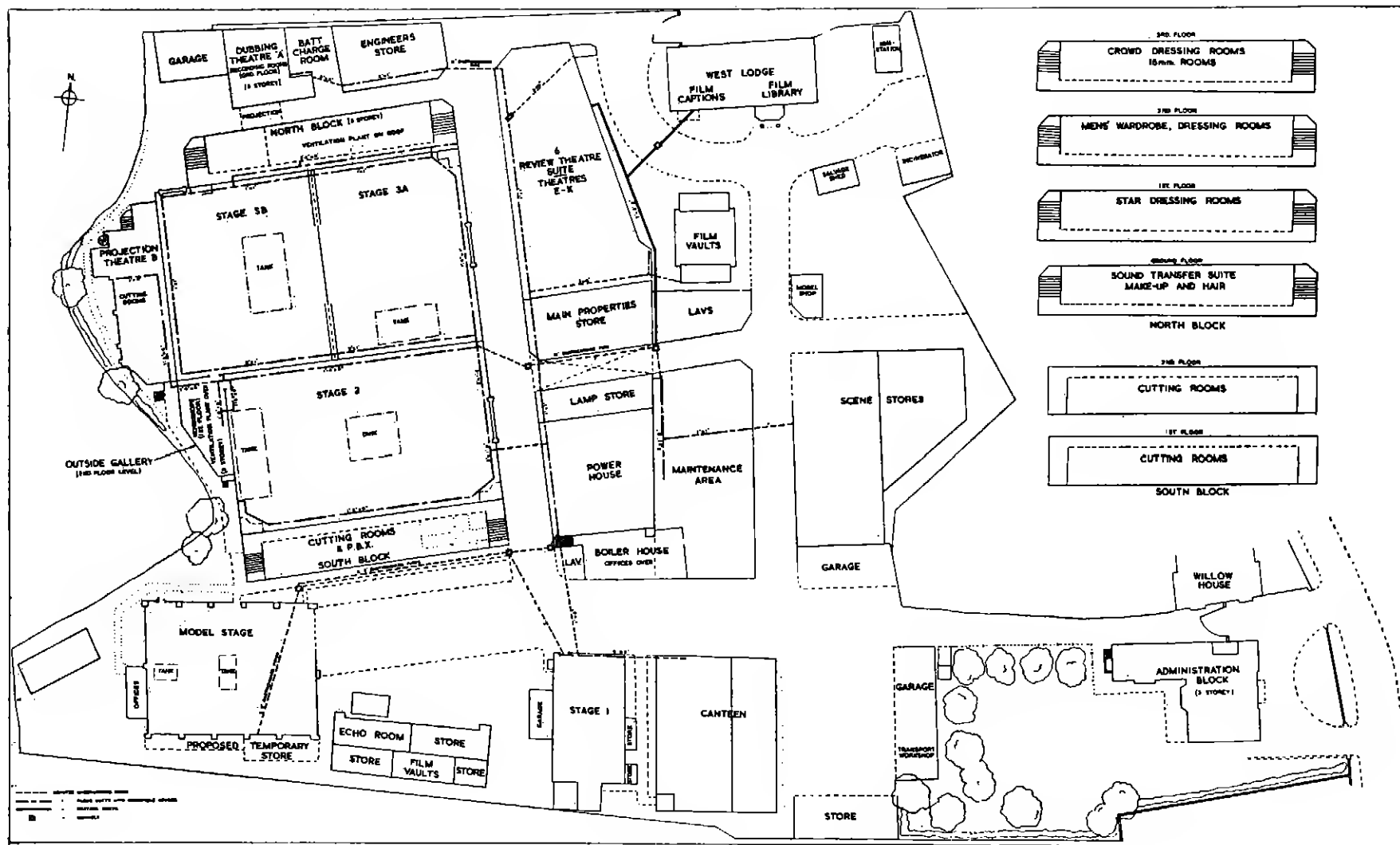


Fig. 1 — General studio layout

5. Layout

This is shown in Fig. 1. The Administrative Block accommodates direction and film operational planning personnel. Thirty-three film editing rooms are situated south and west of the Studio Block, whilst the north end houses the Sound Transfer Suite, the Make-up and Hairdressing Sections, and the dressing rooms. The Film Dubbing Theatre is adjacent to the transfer suite. The Review Suite is located conveniently between the cutting rooms, film library, and film vaults. At present the model stage is used for scenery storage due to the acute shortage of space for this material. The original Power House, containing two diesel generators, has not been altered although new mains input and distribution equipment has been installed.

6. Filming Operations

6.1 General

All film camera operations with the exception of News and locally based regional activities (at Birmingham, Manchester, etc.) are based at Ealing. This applies to all assignments in England and overseas, as well as to all studio filming.

Both 16-mm and 35-mm film are used and a detailed analysis of the respective uses and merits of these gauges was given in the author's paper⁽¹⁾ to the B.K.S. in 1957. As a general principle 16-mm is used where mobility of equipment is essential such as on overseas assignments. 35-mm is used when the highest quality is desired, particularly for film inserts for a live television play or feature programme.

Examples of studio and location filming are shown in Figs. 2, 3, and 4.

6.2 Mobile Filming

It has not been found possible to standardize on any particular type of equipment for this purpose owing to the varied and changing production requirements and to changing technical developments in this field.

Silent film equipment comprises the usual range of Newman Sinclair, Vinten, Mitchell, Eclair, and Arriflex 35-mm and 16-mm cameras. Reflex shutter cameras are preferred to ensure accurate close-tolerance framing. When sound is required, 35-mm equipment comprises: Vinten and Mitchell cameras used in conjunction with a 35-mm magnetic recording van; BBC/G.B.-Kalee Double Film Camcras employing a Cameflex camera (complete

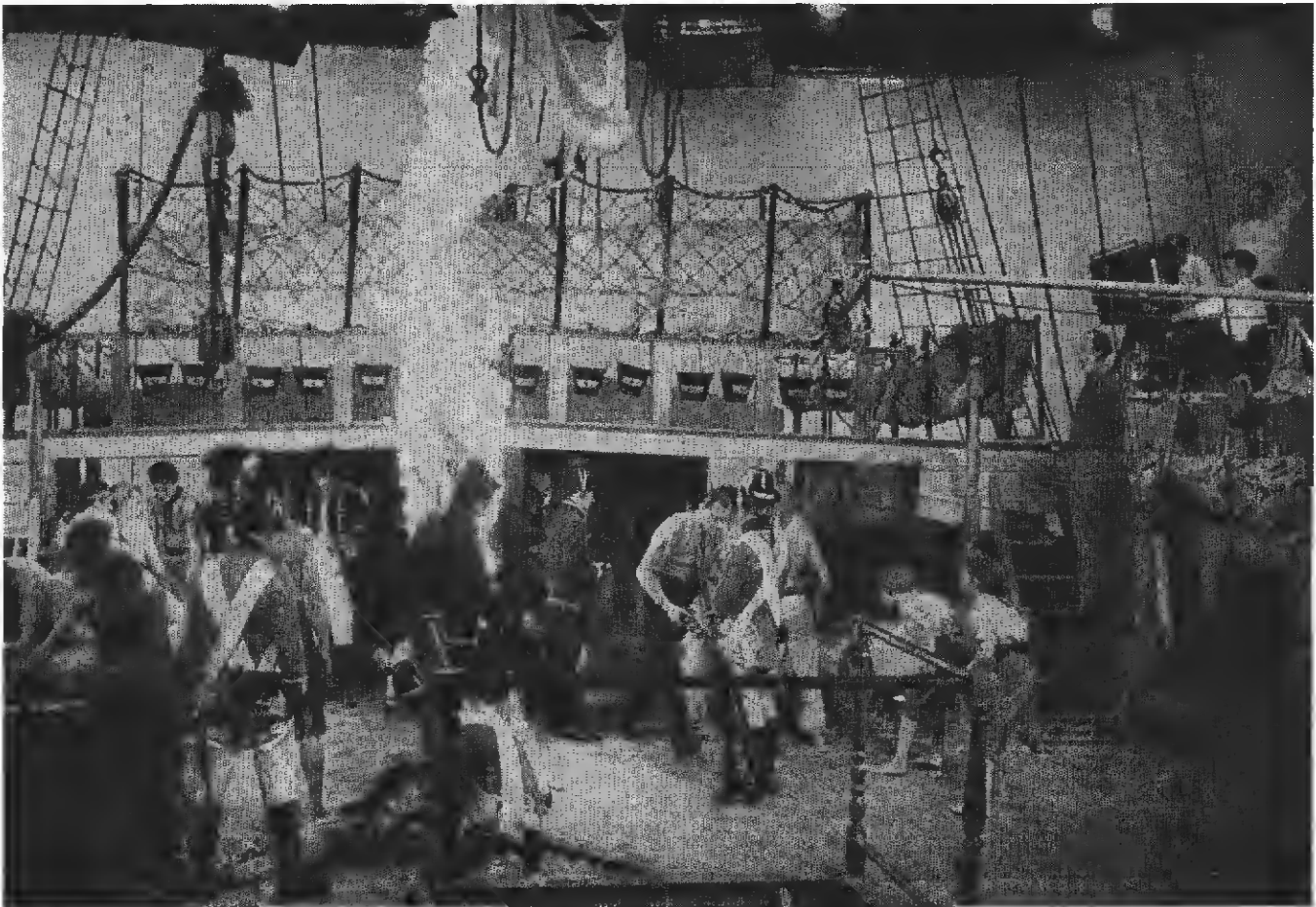


Fig. 2 — Studio 2. Filming sequence for television play Nelson



*Fig. 3 — Studio 2.
Filming sequence for
television opera
Tale of Two Cities*



Fig. 4 — Filming exterior sequence for television play Treasure Island

with 35-mm magnetic recording mechanism, all built into one sound-proof blimp; and Vinten and Mitchell COMOPT (combined picture and sound) cameras. Blimped Arriflex 35-mm cameras used in conjunction with synchronized $\frac{1}{4}$ -in. tape recorders are also proving very suitable for certain types of work.

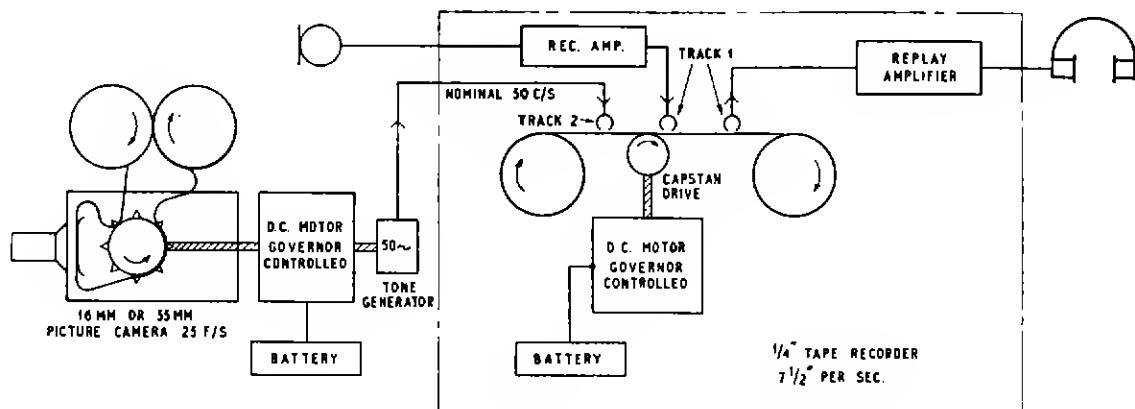
The BBC double film camera was designed to concentrate all the elements necessary for high-quality 35-mm filming within two units, i.e., the camera unit and the sound amplifier. To avoid synchronizing problems and complications, the picture camera and sound recorder are mounted alongside each other and coupled mechanically within the blimp. 35-mm magnetic film is used running at standard television film speed, 25 f/s, thus assuring optimum sound quality and eliminating sound transfer problems.

The 16-mm sound equipment comprises COMMAG (combined picture and sound) cameras using the magnetic-stripe method, with the picture and sound on one film, and double-system equipments usually employing synchronized $\frac{1}{4}$ -in. tape recorders for sound recording.

Striped magnetic combined equipment is used primarily for highly topical programmes where quick handling prior to transmission is essential and simple editing is sufficient. $\frac{1}{4}$ -in. tape separate magnetic sound has been found very suitable for documentary programmes where the slower handling is compensated for by the greater flexibility.

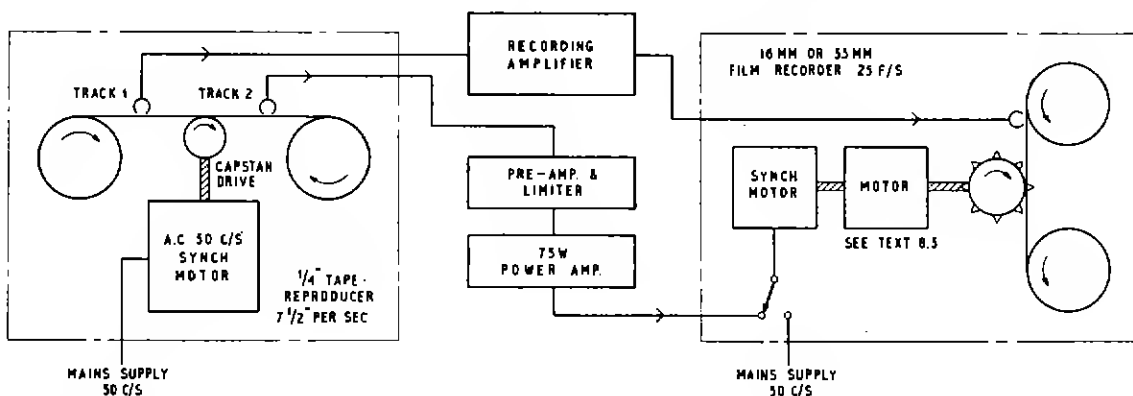
The 'single' system, using magnetic-stripe recording on the edge of the picture film, simplifies the actual filming operation and enables the film to be viewed and checked with sound immediately after processing. It can be edited quickly and rushed on to transmission with minimum

FILMING



TRANSFER

(a) AUTOMATIC



(b) MANUAL

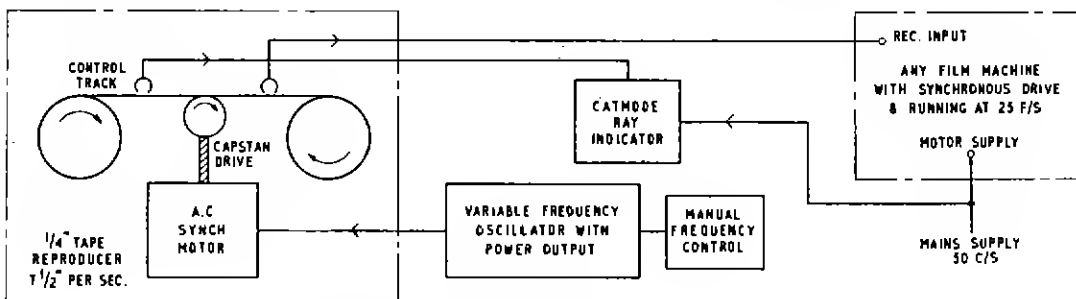


Fig. 5 — Tape synchronizing methods



Fig. 6 — Studio 2. Experimental lighting gantries and rolling tower system

delay without any danger of the sound becoming out of synchronism with the picture. Precise editing is, however, difficult due to the picture and sound being separated by twenty-eight frames. Nevertheless, for topical news and sports type of material the results are acceptable. Various methods of eliminating this twenty-eight-frame separation of picture and sound have been investigated, but have proved impracticable since they introduce delay.

'Double' systems, using separate $\frac{1}{4}$ -in. tape for instance, complicate filming to some extent but provide greater flexibility. Separate sound for effects purposes can be recorded whilst the camera is used for silent shooting elsewhere. Playback on location of any sound recorded is possible, and this is particularly useful in interview work. Some delay is caused by the tape having to be transferred to perforated film, and both sound and picture have then to be synchronized in a cutting room before a preview is possible. This delay is compensated for by the increased flexibility during editing.

The $\frac{1}{4}$ -in. tape system developed by the BBC Designs Department is shown in Fig. 5. It uses an Arriflex 16-mm or 35-mm camera in conjunction with a modified EMI L2B tape recorder. The latter machine is transistorized and arranged for twin-track working. One track carries the programme modulation, and the other a nominal 50-c/s tone produced by a small generator driven by the picture camera. Both the camera and recorder are driven

by low-voltage d.c., governed motors at 25 f/s and $7\frac{1}{2}$ -in./s respectively. A synchronized, perforated, magnetic-film recording of the sound—necessary for editing purposes—is obtained by transferring the $\frac{1}{4}$ -in. tape to film with the 50-c/s tone controlling precisely the speed of the perforated film recorder. This provides a sound film exactly synchronized to the picture film. Correct pitch of the sound depends on accurately controlling the picture camera speed at 25 f/s thus producing an accurate 50-c/s. However, synchronism will be achieved even with wrong camera speeds.

The method is advantageous in that the mobile film equipment is of minimum size and weight, and heavy, expensive synchronizing methods between the picture and sound cameras are unnecessary. The present type of $\frac{1}{4}$ -in. tape recorder used is only really suitable for speech recording, but the system may be extended later to make use of higher grade $\frac{1}{4}$ -in. tape equipment. The transfer equipment is described in greater detail in Section 8.3.

Including Regional cameras and the news equipments at Alexandra Palace there is now a total of 160 film cameras in the television service. Of these, ninety cameras are based at Ealing, with about twenty sound equipments of various types. The proportion of 16-mm to 35-mm equipments in the television service as a whole, including news, is approximately 50-50.

6.3 Studios

6.3.1 General

Fig. 1 shows the film studios available. Studio 2 is used for large or complicated sets. The water tank is particularly useful since at present it is the only facility of this type in the television service. Studio 3A is used for general filming whilst 3B is restricted to rehearsals and very simple filming of the interview or close-up type.

Whilst it is generally true that television film operations ideally require a number of small studios, compared with the few large studios necessary for feature production, the large Studio 2 is proving in practice very useful for the following reasons:

- (a) Television productions which require very large sets, or very complicated scene changes, often have certain sequences prefilmed in order to reduce live television studio floor production complications, and television studio booking time. This entails the pre-erection of these sets at Ealing and requires a considerable floor area. Typical examples are shown in Figs. 2 and 3.
- (b) One large studio enables sequences involving several small sets to be filmed consecutively with minimum delay, thus economizing in time spent on the set by technical staff and artists.
- (c) A big set can remain erected over a period and still allow smaller sequences of another production to be filmed in the meantime.

The studios have not been modified to date except as regards experiments in lighting methods to speed up production. (See Section 6.3.3.)

6.3.2 Equipment used for Studio Filming

The camera and sound equipment comprises Vinten, Everest, and Mitchell 35-mm blimped cameras used in conjunction with either a mobile 35-mm magnetic sound truck, or a static 35-mm channel. The BBC double camera is also used in the studios, particularly for the 'head-and-shoulder' type of interview and for commentary work. Floor-type sound mixers are used and the whole set-up conforms closely to standard film practice.

Still and moving back-projection machines are used as in standard film studio practice.

Standard camera dollies and cranes are used in conjunction with metal tracking rails. The provision of smooth, quiet, television-studio-type floors to allow camera movement without the use of rails would undoubtedly speed up production, but the expense is not felt to be justified at present.

6.3.3 Lighting

110-V d.c. lighting is used in the studios at Ealing. After considerable experiment, a very satisfactory lighting system for television filming purposes has been evolved. This comprises a combination of catwalks, suspended in a set pattern, together with a number of rolling towers. The experimental set-up in Studio 2 is shown in Fig. 6. Plans are now in hand to apply this technique in a more permanent fashion to all three studios, using gantry layouts approximately as shown in Fig. 7. The whole system will

normally be positioned some 16 ft above ground with the exception of sections A, which will be at a height of approximately 20 ft to allow the erection of a cyclorama or similar backcloth as a background for long shots. Provision will be made for raising sections C to approximately 20 ft, when required, to accommodate larger sets.

The Design and Supply, and Production Departments are provided with studio floor plans showing the disposition of the fixed lighting catwalks and, as far as possible, these departments plan their sets and production arrangements to utilize these with the minimum of alteration.

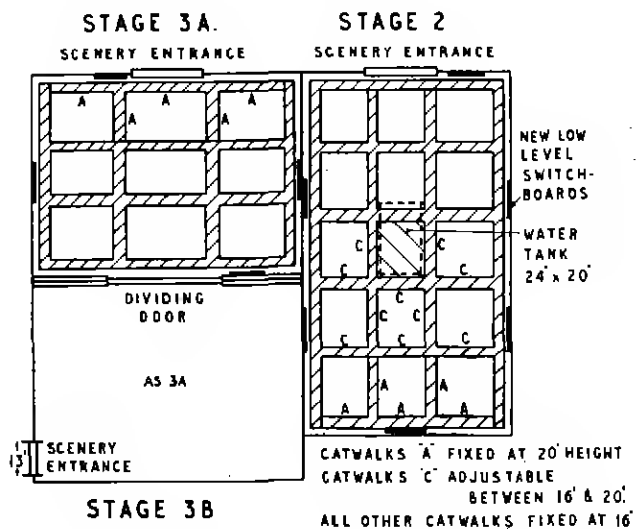


Fig. 7 — Studio lighting—proposed gantry system

Experience has shown that these gantries can be equipped with a basic array of illuminators which can be used relatively unaltered for a large proportion of sets. Any alterations that are found necessary, together with the adjustment and switching of the lamps, are easily accomplished from the gantries.

Additional mobile lighting is available on the rolling towers seen in Fig. 6.

This system has proved very successful and probably represents a good economic compromise between the standard feature film lighting methods, which tend to be too slow for television filming, and television studio systems which are necessarily expensive and not justified for this type of work. Although at present the lighting system is controlled and switched from above, at lighting-grid level, it is planned to replace this arrangement by a number of smaller lighting switchboards, each of 75-kW capacity, at floor level around all four walls of each of the studios, as indicated in Fig. 7. This arrangement will improve operational flexibility and also enable the lighting staff to operate with increased efficiency.

Each switchboard will be capable of feeding a number of mobile cubicles arranged with sockets for the connection of the illuminators. A new lighting plug-and-socket system, suitable for both interior and exterior working, is planned, and this is described in Section 6.4.

6.3.4 Lighting Standards

Every effort is made to match the lighting employed for the film sequences at Ealing to the lighting levels which will be used in the television studio for the live production as a whole.

The proportion of flat lighting equipment using multiple light units has been increased compared to that used for feature filming, and film cameramen are kept informed of the telecine and live transmission requirements. It is normal practice for the lighting supervisor of the live television production to be present as far as possible during prefilming sessions at Ealing.

6.3.5 Scenery

There are no scenery construction facilities at Ealing. This work is carried out at the main Design and Supply workshops already operating at the BBC's new Television Centre at White City. Scenery is transported to Ealing by road. This method has undoubted advantages as regards economy of set construction, staff, and facilities, but very careful planning is necessary to avoid delays on the film studio floors. A selection of standard sets is retained at Ealing, together with a reasonably well-stocked property store.

6.4 Exterior Lighting

Existing plug-and-socket systems of the Kliegl type used for film illuminators are unsuitable since they are not designed for exterior use under bad weather conditions, or for use above 110 V. (See B.S.S. 828.) In order to overcome this, and ensure that all BBC film-lighting equipment can be used up to 240 V and conform to the safety standards necessary in such an organization, a new plug-and-socket system is being planned. This will be reasonably weather-proof and suitable for use with either 240-V or 110-V supplies. The system will provide cables and connector units capable of dealing with the complete range of lighting assignments, from the small 'one man' simple filming sessions up to a large location filming operation. Moulded rubber plugs and sockets will be used together with compact, weatherproof connection cubicles. It is hoped to achieve a high degree of safety and reliability with at least the same flexibility provided by the existing Kliegl system.

It is proposed to use this system both for exterior and interior illuminators for film work, in order to make maximum use of the available lighting equipment. Standardization of the plugs and sockets will enable, for instance, studio illuminators to be used on the adjacent exterior 'lot' with complete safety under all weather conditions.

6.5 Film Caption Facilities

Titles, captions, and animated diagrams on film are required for complete films, for film sequences, and for direct insertion in live television programmes. Increasing use is also being made of filmed titles for television programmes, since this method reduces studio floor complications which arise when television cameras are used in conjunction with caption cards or roller captions.

A modern, highly flexible, 35-mm rostrum has been installed at Ealing for this work. This is shown in Fig. 8

and comprises a British Newall 35-mm camera mounted on a rotatable carriage arranged to travel up and down on two vertical columns. In addition, the caption table is arranged to travel from north to south, or east to west, and the complete rostrum can be quickly set up to provide any desired position of the camera or caption.

The camera can be run continuously or 'frame by frame' for stop action or cartoon work.

Automatic follow focus is fitted so that the camera lens is in focus at all positions of the camera carriage. This greatly facilitates 'zoom' shots and speeds up operation of the table generally.

All movements are motorized and equipped with push-button and variable-speed controls.

Mercury vapour lighting is employed to reduce shadows and improve contrast.

7. Editing

7.1 General

There are thirty-two cutting rooms now in service at Ealing. Approximately twenty are equipped for 35-mm film and ten for 16-mm, with the two remaining rooms allocated to 35-mm and 16-mm negative cutting. This proportion of 35-mm to 16-mm does not represent a true picture of the balance between the two gauges throughout the television service. News Film Operations based at

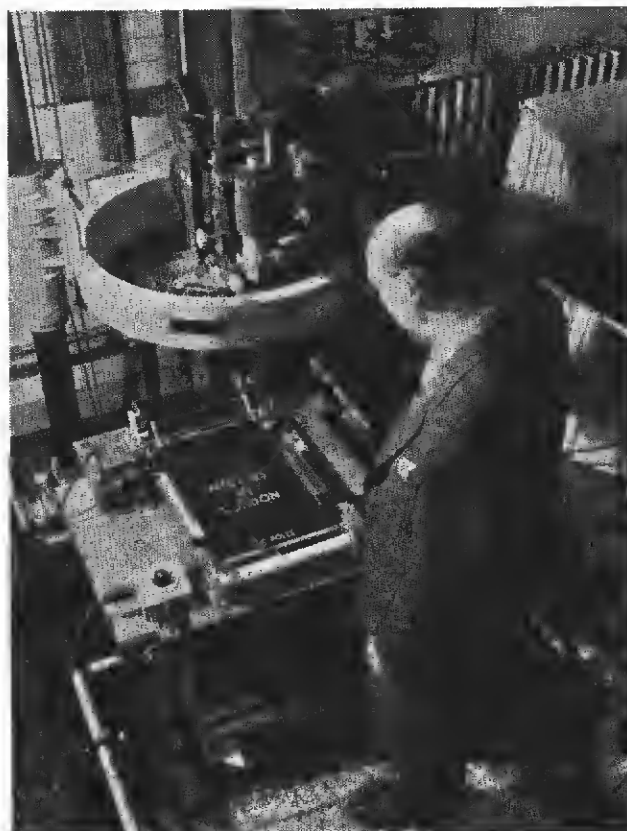


Fig. 8 — 35-mm film titling rostrum



Fig. 9 — 16-mm editing equipment

Alexandra Palace work almost entirely on 16-mm and this gauge is also used for some of the highly topical programmes (Sportsview, etc.) which are serviced from Lime Grove.

It is now standard practice to restrict each cutting room to one gauge of film and to restrict operations in each room to one job at a time. Each room is provided with a reasonably standard set of apparatus comprising a fully equipped editing machine or machines, a comprehensive synchronizing bench and a high-grade joiner. This results in a high degree of flexibility. There are exceptions to this rule of course, sometimes the basic set of equipment is spread over two adjacent rooms, but in general the above plan is adhered to. A viewing or editing machine in this context is classed as a fully equipped machine which will enable the picture to be viewed and any type of sound (combined or separate) to be played back.

An exception to the cutting room film gauge standardization policy is necessary in respect of magnetic sound

film. The long-term plan is to avoid mixing of the film gauges, i.e. 35-mm picture film will use 35-mm magnetic sound film and 16-mm picture film will use 16-mm magnetic film. However, a transition period is still operative in which 35-mm magnetic film is used with both 35-mm and 16-mm picture film (see the foreground Fig. 9). This necessitates a certain amount of 35-mm magnetic sound equipment in 16-mm editing rooms at present, although it is hoped that eventually this complication will be eliminated. All cutting rooms are wired in standard fashion and decorated with washable paint to facilitate regular cleaning.

7.2 35-mm Equipment

35-mm equipment comprises continuous motion machines of the Editola variety, and intermittent motion, Moviola type editing machines. Foot-operated precision joiners and robot automatic joiners are used together with four- or six-way synchronizing benches. The continuous

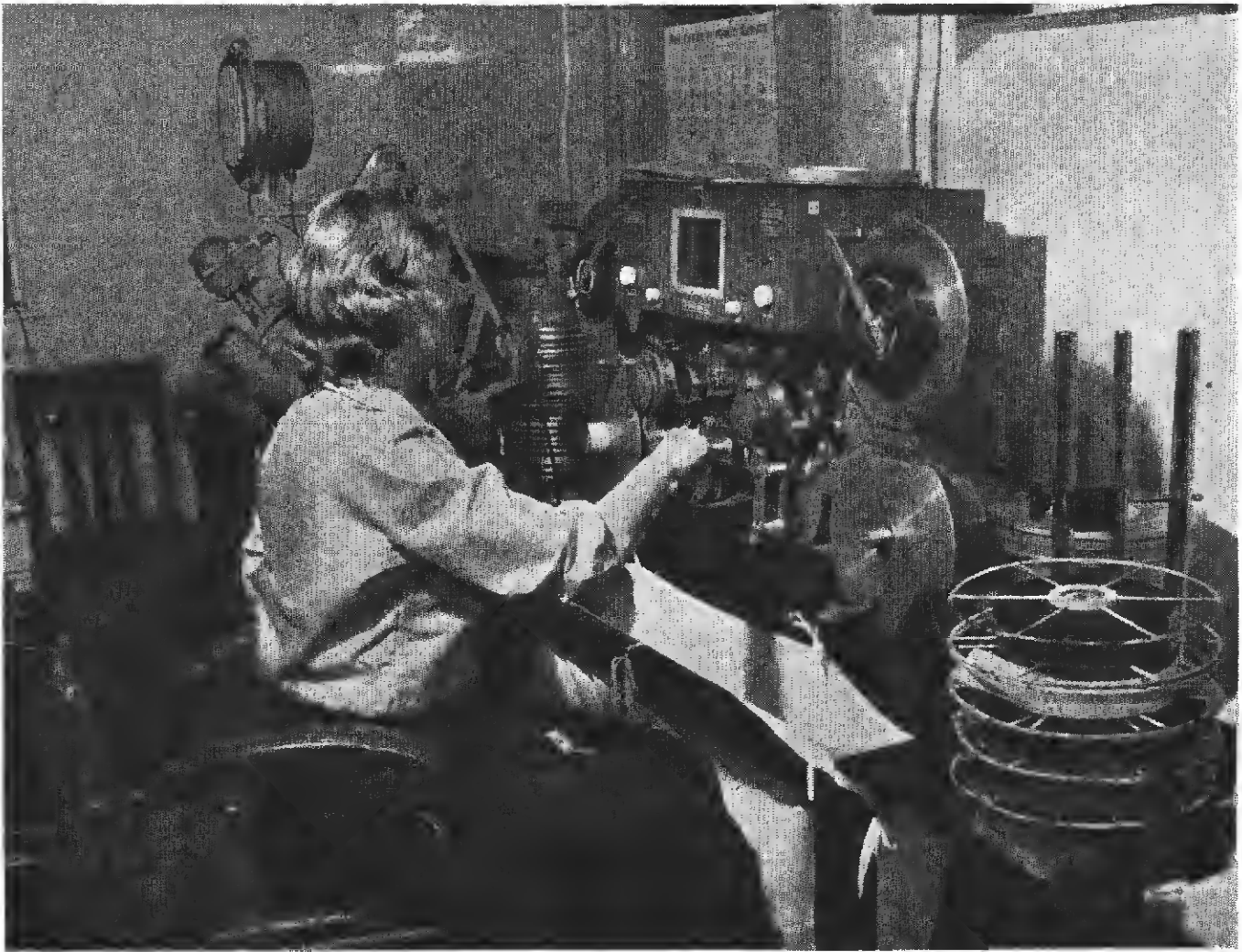


Fig. 10 — 35-mm editing equipment

motion machines are preferred for direct negative editing since these are less liable to damage film than an intermittent machine. Fig. 10 shows a machine of this type in use.

7.3 16-mm Equipment

In 16-mm gauge, continuous motion machines are found to be essential in order to reduce film damage when the editing of original negatives, or transmission prints, is required. Examples of this type of equipment are the German Steenbeck seen in the foreground of Fig. 9 and the new Acmade Mark II, shown in Fig. 11. Each of these machines provides a wide range of facilities not hitherto available in one equipment. This leads to increased ease of operation; for instance, the Acmade Mark II machine, illustrated in Fig. 11, provides the following facilities and deals with the listed types of film:

- (a) 16-mm Silent.
- (b) 16-mm COMOPT or COMMAG.
- (c) 16-mm SEPMAG, either centre or edge track.

- (d) Very quick lace-up.
- (e) 2 000-ft film capacity.
- (f) Foot or band control.
- (g) Synchronous 25-f/s drive.
- (h) Variable-speed drive 2–50 f/s.
- (i) Instantaneous stop at any speed.
- (j) Fast rewind.
- (k) Simple splicing on the machine.
- (l) Erasing of unwanted magnetic sound.
- (m) Simultaneous checking of combined and separate sound.
- (n) Time and frame counters.

A modern 16-mm editing machine for television film purposes is rapidly becoming a very complicated piece of equipment.

7.4 Magnetic Film Editing

All synchronizers are equipped with magnetic heads for checking the sound track. This has been found to be an in-

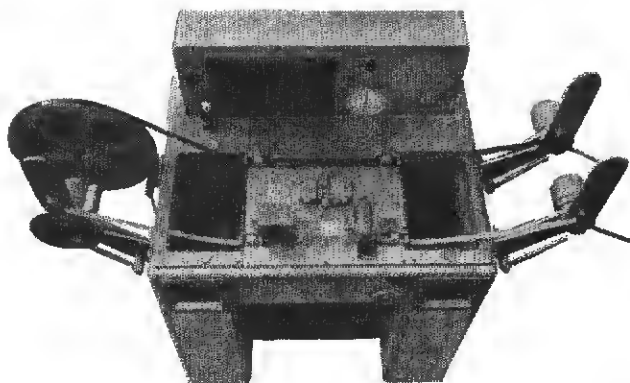


Fig. 11 — New design of 16-mm editing machine

valuable aid in editing magnetic film since the magnetic sound, unlike photographic track, is of course invisible. Magnetic film is joined using high-precision foot splicers

employing a standard overlap join. The splicer blades are periodically degaussed to avoid any deleterious effect on the magnetic tracks.

This method of joining magnetic film is not perfect, but it has been found the most reliable available to date. Butt joining, using either a special butt-weld type of splicer or the perforated adhesive tape method, has not been found completely satisfactory although the tape method is useful for film repair work.

7.5 Footage Indication

Film 'footage' is recorded and indicated throughout the Television Film Studios by counting film frames. The basis of this method is the 35-mm footage indicator in which each digit represents one foot, or sixteen frames, of 35-mm film. The same counter is used for 16-mm with one digit still representing sixteen frames, although with this gauge the length of film involved is different. This method has been found to be the most successful of the various alternatives possible in a system using both gauges of film.



Fig. 12 — Sound transfer suite—view from listening room

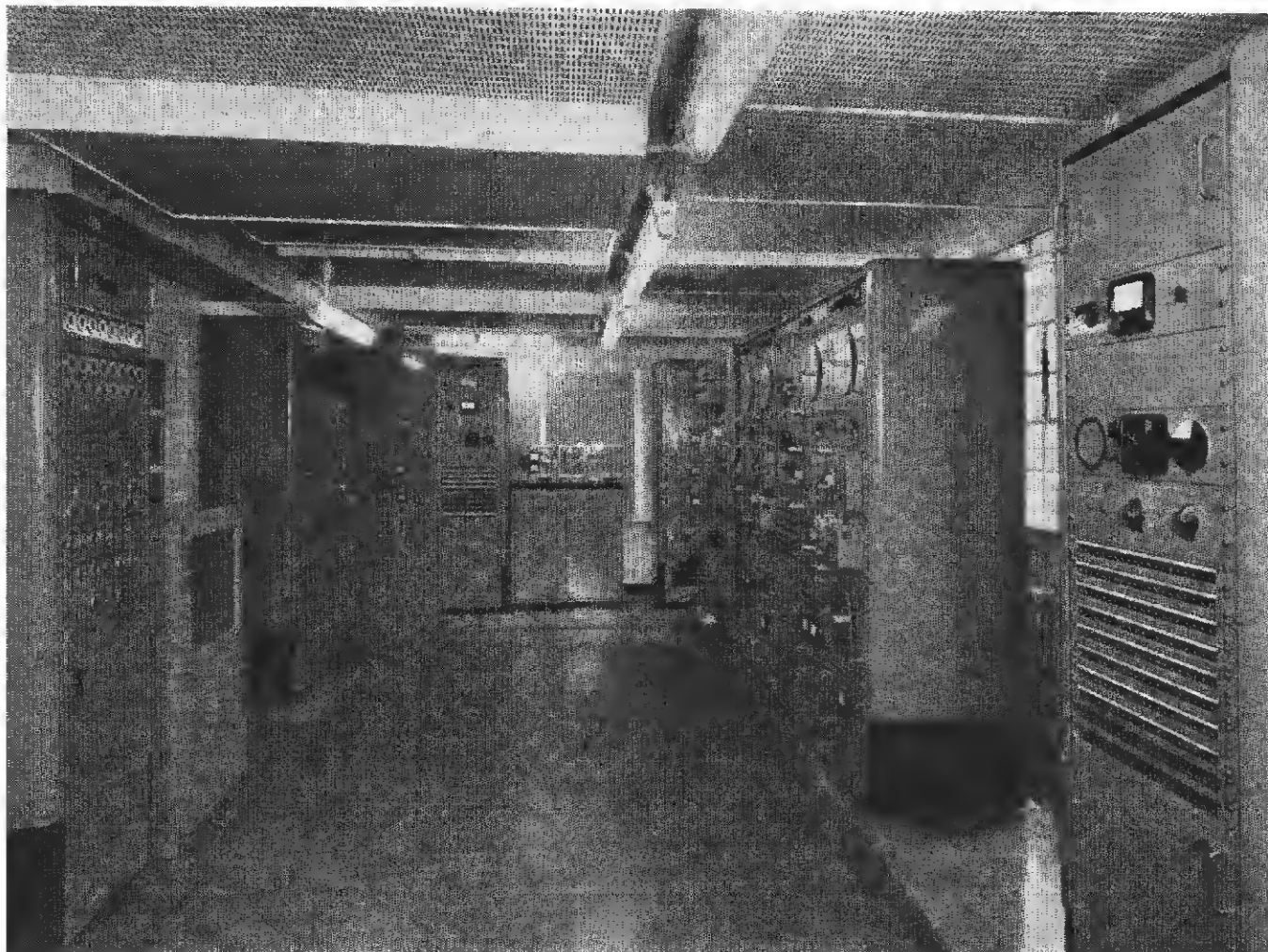


Fig. 13 — Sound transfer suite—general view of optical and magnetic recording machines

8. Film Transfer Suite

8.1 General

The increasing complexity of film operations in television results in the need for a central sound reproducing and recording room equipped to copy and transfer sound of any type or gauge.

The operational requirements can be listed as follows:

- (a) Transfer of $\frac{1}{4}$ -in. tape (original sound) to either 16-mm or 35-mm perforated magnetic film for editing and subsequent dubbing.
- (b) Production of 'safe', or duplicate, copies of either 16-mm or 35-mm original recordings.
- (c) Transfer from 35-mm to 16-mm or vice versa to achieve picture and sound gauge standardization through editing and dubbing.
- (d) Selection of required 'takes' from an original roll of complete location or studio sound. These are transferred to shorter rolls for editing thus avoiding the continual breaking down of new 400-ft or 1 000-ft rolls which can thus be preserved for original shooting.
- (e) Transfer of sound from disk to film, to facilitate accurately synchronized track laying for dubbing purposes. Examples of effects requiring this treatment are gun shots, certain car noises, etc.
- (f) Transfer of non-synchronous sound from film to disk to facilitate dubbing. (Disk playback is available in the dubbing operation.) This reduces track laying in the editing process and can be employed for such effects as crowd noises, cheering, etc.
- (g) Transfer of magnetic sound of either gauge to optical sound in either gauge to facilitate production of COMOPT prints.
- (h) Transfer operations necessary to facilitate interchange of films made to different standards, i.e. 16-mm edge track (200 mil) to 16-mm centre track (200 mil).
- (i) Quality checking of sound films.

A sound transfer room equipped for the above operations has been installed at Ealing and is shown in Figs. 12-14. The equipment schematic is shown in Fig. 15.

8.2 Details of the Machines

- (i) 16-mm Magnetic Recorder/Reproducer, 2 000-ft ca-

capacity—with interchangeable magnetic heads arranged for edge 100-mil (stripe), edge 200-mil, or centre 200-mil recording and reproduction. Interlock and synchronous drive (see Appendix B).

- (ii) *16-mm Magnetic/Optical Reproducer*, 2 000-ft capacity. Interchangeable magnetic heads for edge 100-mil (stripe) track, edge 200-mil, or centre 200-mil reproduction. Also fitted with optical sound reproducing head. Interlock and synchronous drive.
- (iii) *35-mm Magnetic Recorder/Reproducer*, 2 000-ft capacity. Arranged with pluggable magnetic heads designed to record/reproduce any of the standard 35-mm tracks 1, 2 or 3. Interlock and synchronous drive.
- (iv) *35-mm Magnetic/Optical Reproducer*, 2 000-ft capacity. Arranged to reproduce standard magnetic tracks 1, 2 or 3 and also CinemaScope tracks. Also fitted with an optical sound reproducing head designed for optical standard 100-mil or push-pull 200-mil tracks. Interlock and synchronous drive.
- (v) *16-mm Optical Recorder* of very high grade per-

formance, 1 000-ft capacity. Designed to record either 'negative' or 'direct positive' tracks with standard emulsion positions and with noise reduction.

- (vi) *35-mm Optical Recorder*, 1 000-ft capacity. Designed to record 'negative' or 'direct positive' 100-mil or 200-mil tracks with noise reduction.
- (vii) *Disk Reproducer—Modified BBC Type DRD/5.*⁽²⁾ Arranged to reproduce 33 $\frac{1}{3}$, 45, or 78 r.p.m. disks with appropriate equalization.
- (viii) *Disk Recorder*, 78 r.p.m. only with synchronous drive.
- (ix) *35-mm Magnetic Recorder*, 1 000-ft capacity. Arranged to record track No. 1 only. This is a special tape transfer machine fitted with a dual drive system. Drive condition 'A' operates the recorder synchronously from mains supplies. Drive condition 'B' enables the speed of the machine to be controlled automatically from a pilot frequency recorded on $\frac{1}{4}$ -in. tape for tape-to-film synchronous transfer. (See Section 6.2.)

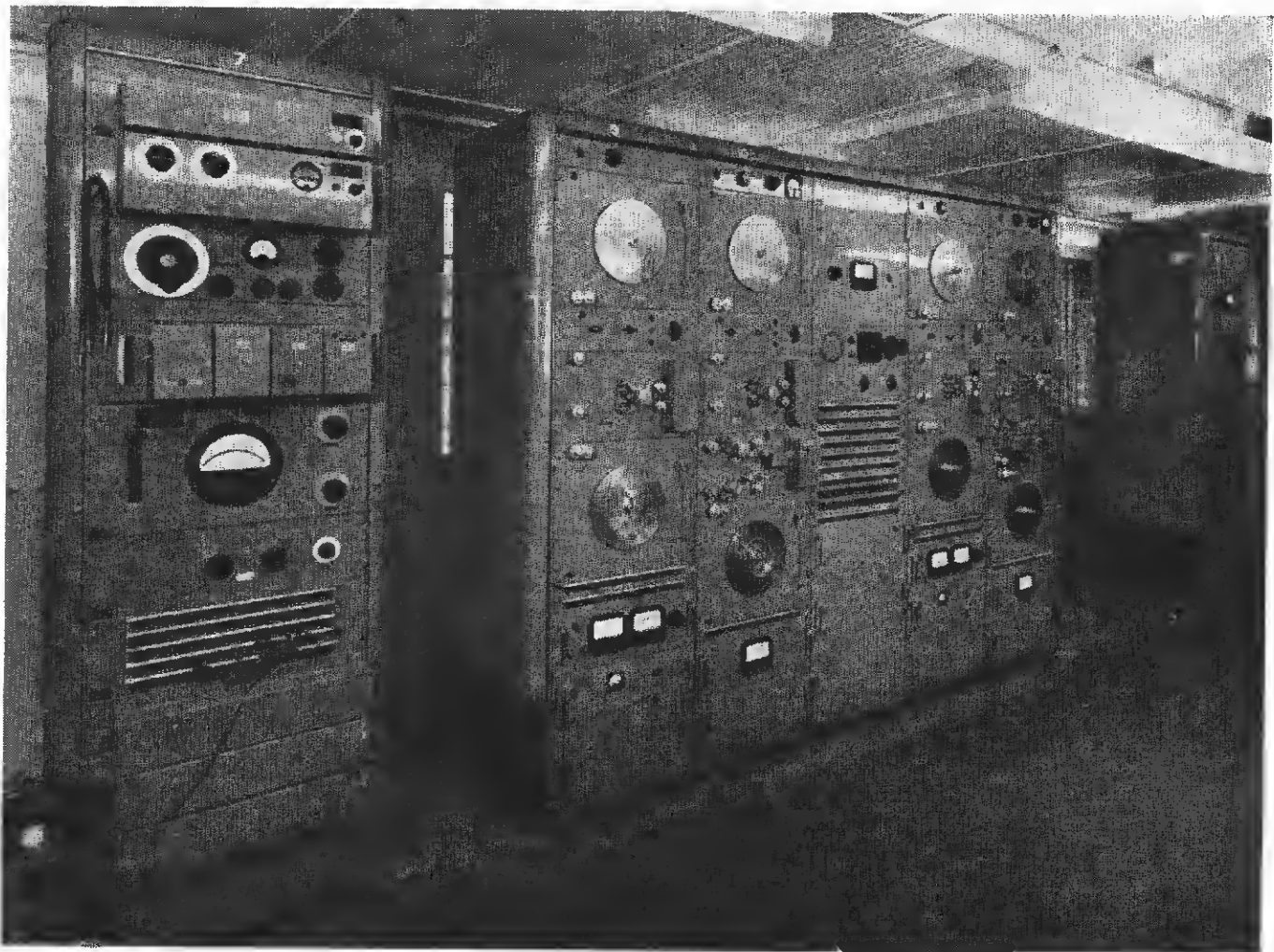


Fig. 14 — Sound transfer suite—35-mm and 16-mm magnetic recording machines

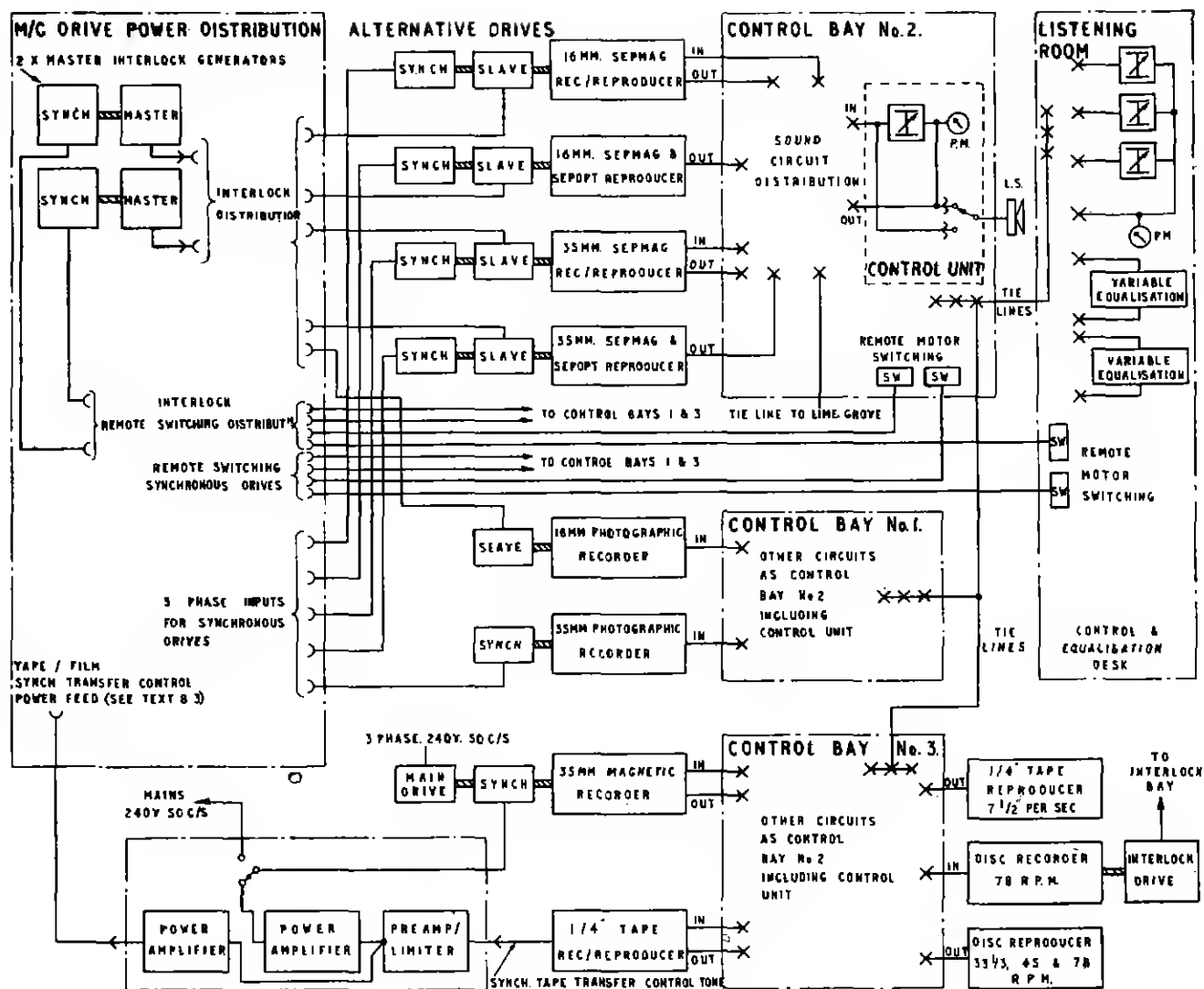


Fig. 15 — Transfer suite schematic

- (x) $\frac{1}{4}$ -in. Tape Reproducer/Recorder. This is a high-grade machine arranged to operate at either $7\frac{1}{2}$, 15, or 30-in. per second. It is fitted with alternative twin-track or single-track head assemblies. The twin-track assembly enables the machine to be used for $\frac{1}{4}$ -in. tape-to-film synchronous transfer (see Section 6.2) using the BBC method.
- (xi) $\frac{1}{4}$ -in. Tape Reproducer. This is a special machine in which the tape capstan motor is driven by an oscillator fitted with manual frequency control. A cathode ray indicator is fitted enabling the mains frequency to be compared with the frequency of any type of control tone which might be on the tape. A selection of playback heads is fitted to deal with the different systems in use—Leavers-Rich, Maihak, Perfectone, etc. This equipment enables synchronous tape-to-film transfer to be carried out since the cathode ray frequency comparator and manual speed control enable the tape speed to be adjusted to keep the control tone frequency and the perforated

film machine speed (controlled by the mains frequency) precisely in step. It has been found that with closely controlled camera and recorder speeds little adjustment is necessary.

8.3 Tape to Film Transfer

In addition to the above (8.2(ix), (x), and (xi)) further automatic tape-to-film transfer capacity is available since the machines referred to in paragraphs (i) and (iii) above are also arranged to be controlled, if required, by an external control frequency. These machines are fitted as standard with a dual synchronous interlock motor for alternative synchronous or interlock drives. When external frequency control is required, the rotor windings of the interlock drive motor are resistively loaded to enable it to run as an induction motor thus supplying a high percentage of the power required for driving the machine. The control frequency is fed to the synchronous motor via a 120-W amplifier to provide precise control of the film speed.

8.4 Control Positions and Interlock Distribution Bay

Three control positions are installed at convenient points in the transfer room to provide a method of linking reproducers and recorders and to provide volume control and centralized synchronous or interlock motor switching.

An interlock control and distribution bay is installed (Fig. 13, left), equipped with two master interlock generators. Plugging is provided to interlock any pair of machines. Control of the master distributors is available on the control positions. Circuits are also provided to enable the transfer machines to operate in interlock with the dubbing theatre distributors if required. These are provided for emergency use only.

Direct sound and control lines are provided to the dubbing theatre mixer room at Lime Grove to enable transfers to take place between Ealing and Lime Grove. Further extension of these lines can be made, if necessary, at Lime Grove to enable emergency transfers to be carried out from any other BBC centre.

8.5 Listening Room

A high-grade listening/mixer room, shown in Fig. 12, is provided for the following purposes:

- (a) Quality checking of recordings.
- (b) Accurate control of any transfer operation with facilities for high-grade listening and frequency-response equalization if required.
- (c) Frequency-response correction during transfer to alleviate faults on original recordings.

The mixer desk fitted, also seen in Fig. 12, is, in essence, a more comprehensive control position and can be plugged into the system from any of the three recording room control bays. Talk-back is provided to each of the control bays together with remote control of the interlock generators or individual machines.

The transfer suite has proved particularly successful and has been operating continuously during the nine months it has been in service providing an invaluable central 'clearing house' for all film production sound tracks.

8.6 Reproducing and Recording Standards

Some reference should be made here to the magnetic film recording standards which are adhered to in the BBC.

As regards frequency response, the C.C.I.R. standard for magnetic material running at 15 in. per second and 7½ in. per second is adhered to for 35-mm and 16-mm film respectively. This is in accordance with European Broadcasting Union agreements.

Track positions are S.M.P.T.E. Track No. 1 for 35-mm and, at present, edge track 200-mil for 16-mm film. In accordance with recent European Broadcasting Union agreements the BBC is also equipped (in the transfer suite) to send, if requested, or to receive 16-mm SEPMAg film to the E.B.U. standard which is as follows:

Primary standard—centre 200-mil track.

Secondary standard—edge 100-mil track.

200-mil centre track has technical advantages over edge track and the BBC has decided to change to this E.B.U.

standard as soon as possible. Reproducing machines will be arranged to play back both types of track since a considerable amount of edge track material is received for direct transmission particularly from the U.S.A. and Canada.

9. Film Review Suite

9.1 General

Prior to the installation of this suite, film viewing and checking facilities in the television service suffered from the following disadvantages:

- (a) All theatres were different physically and acoustically and also as regards equipment, owing principally to the fact that all these areas had been taken over by the television service as part of existing premises. This resulted not only in varying standards of assessment, but also in individual preferences being expressed by producers for particular viewing rooms.
- (b) The increasing variety of the types of film used, particularly with regard to sound tracks, made the provision of comprehensive equipment for all these areas very difficult both as regards space and cost.
- (c) The breakdown of any one item could result in serious inconvenience especially with an imminent transmission time for the film.
- (d) Operation and maintenance of the areas were difficult owing to the small size of the projection rooms, lack of standby equipment, and wide dispersal of the various areas.

In an attempt to overcome these difficulties a Review Suite was planned at Ealing comprising six identical viewing rooms serviced by a single long projection area. The latter was designed to handle all the various types of programme material with a reasonable amount of apparatus, bearing in mind that a diversity factor was possible in respect of the number of complicated playbacks likely to be required simultaneously.

The common projection area has considerably improved operational methods and maintenance conditions. The suite enables a standard performance to be easily attained in all theatres.

9.2 Direct Projection Versus Telecine Viewing

Direct projection equipment was provided in preference to telecine viewing almost entirely on the grounds of finance, the difference in cost between twelve projectors and twelve telecine machines being very considerable. Other factors were simplified operation and maintenance and the elimination of possible picture quality variations, thus making assessment of the technical quality of the film easier. The viewing of film by telecine on a television monitor has considerable technical advantages, however, since the film is seen under transmission conditions. Also, negative film can be phase reversed and viewed as a 'positive'. Accordingly space has been allowed in the suite for the addition of one or two flying-spot telecine scanners at a later date together with monitors in the theatres if experience shows this to be desirable and the extra cost can be justified.

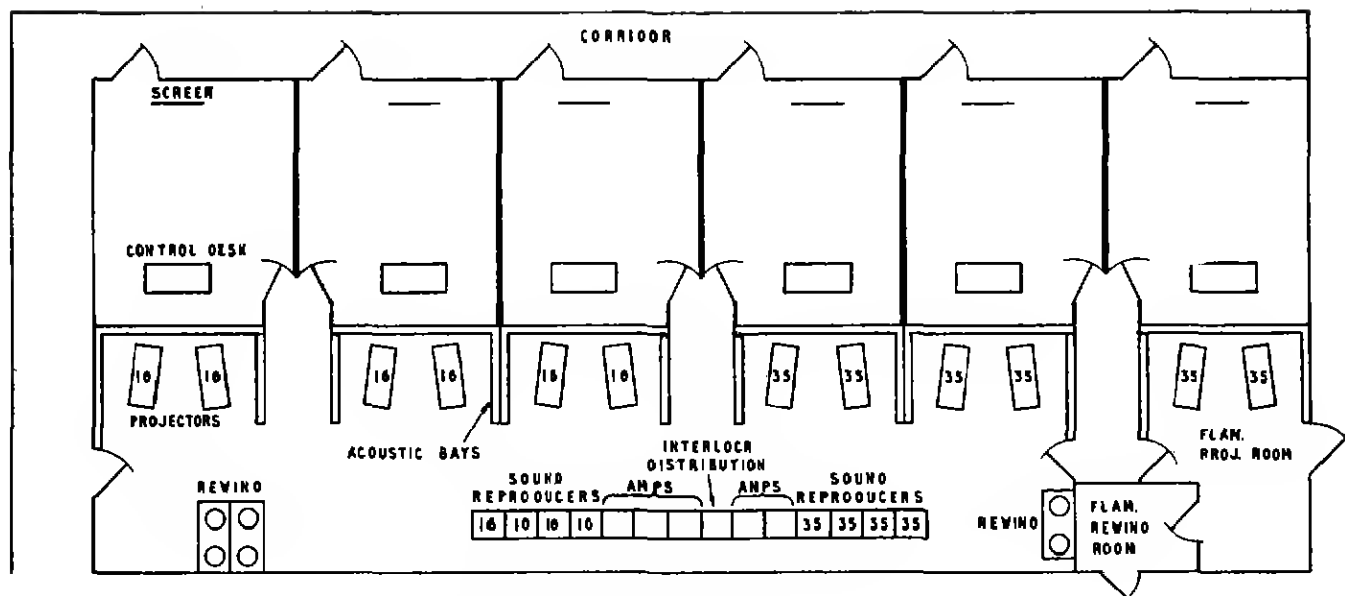


Fig. 16 — Six review theatre suite—layout

9.3 Layout

The general layout of the area is shown in Fig. 16 whilst the equipment is illustrated in Figs. 17–20. A schematic of the facilities is shown in Fig. 21. Three 16-mm theatres and three 35-mm theatres are provided.

A pair of projectors of identical gauge are allocated to each theatre, this method having been found preferable to mixed gauge operation. The pairs of machines are installed in acoustically separated bays to avoid monitor loudspeaker interference.

The projection equipment for one of the 35-mm theatres has been segregated to enable it to be used for inflammable film if required. The remainder of the projection area is restricted to non-inflammable film with a resultant decrease in cost of construction and increased flexibility.

9.4 Equipment General

Each projector is equipped for combined sound—COMOPT only in the case of the non-flam 35-mm machines, and COMOPT and COMMAG in the case of the 16-mm machines. One 35-mm theatre is equipped for CinemaScope films in addition to those of standard aspect ratio.

A central set of sound reproducers and bays are installed along the rear of the projection room, as seen in Fig. 19. These comprise the following:

- All the sound amplifier equipment and power units with the exception of the head amplifiers.
- Four 16-mm reproducers—SEPMAG or SEPOPT—each with interlock drives.
- Four 35-mm reproducers—SEPMAG or SEPOPT—each with interlock drives.
- Master interlock distributor for individual running of above machines.

(e) Master interlock selection bay to enable any of the above machines to be coupled to any projector.

(f) One bay equipped with test apparatus and central jackfield.

9.5 16-mm Projectors

The 16-mm projectors are Bell and Howell Type 609 equipped for SEPOPT and SEPMAG sound. A professional type sound head is fitted. Each projector carries a drive unit in the base consisting of a synchronous motor coupled to an interlock master drive unit. The interlock master drives a slave motor mounted on the projector head plus any sound reproducer, which can be coupled up through the interlock selection bay. One pair of projectors is capable of running at 16 f/s, in addition to 25 f/s for showing of silent material shot at that speed. The other two pairs are capable of running at 50 f/s in addition to 25 f/s to facilitate high-speed checking of 'rushes'.

9.6 35-mm Projectors

The 35-mm projectors are G.B.-Kalee Type GK21 machines each equipped for COMOPT sound. The drive on each projector consists of a synchronous motor driving the projector mechanism direct. An interlock master is also coupled to the main drive and this can be used to drive a separate sound reproducer as required. The two 35-mm projectors in the segregated inflammable film area may be equipped for 35-mm SEPMAG operation, in addition to COMOPT sound, since playback using the separate 35-mm SEPMAG reproducers is difficult owing to the physical separation of the two equipments.

9.7 Illuminants

Arc illuminants are fitted to all machines in order to ensure that the colour of the projected picture bears a close

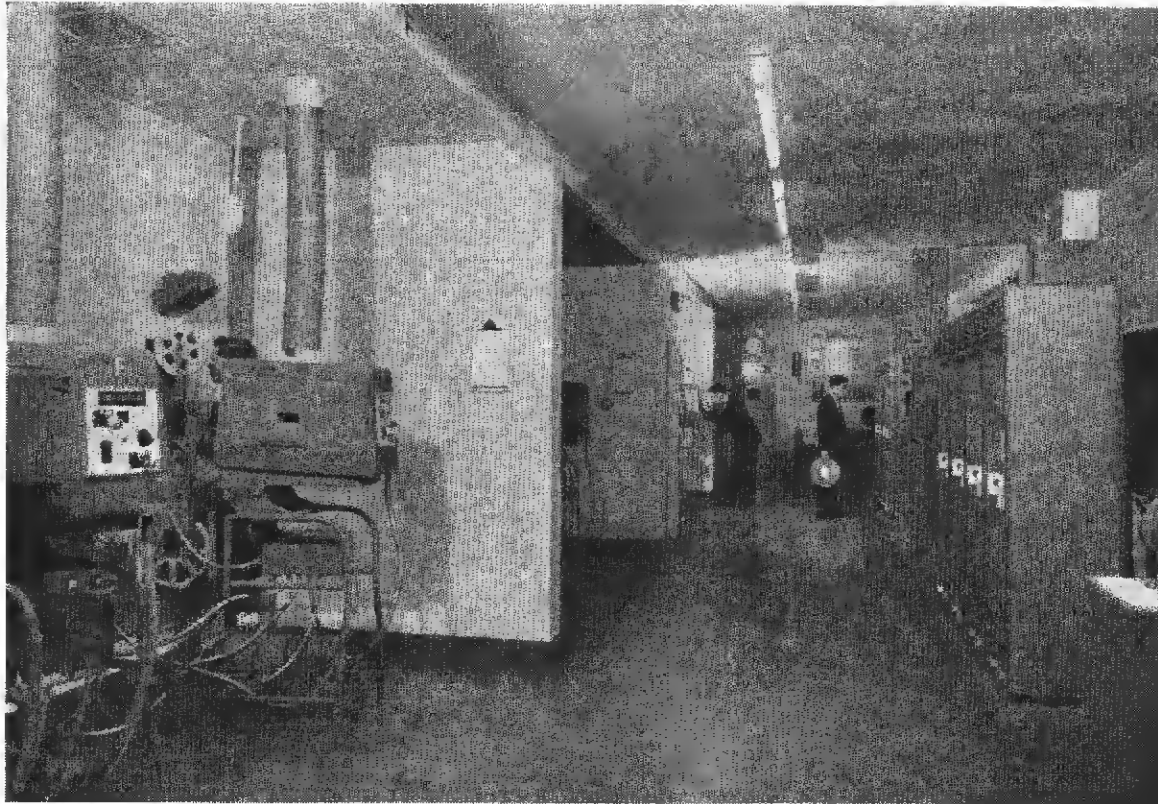


Fig. 17 — Six review theatre suite—general view of section of projection room

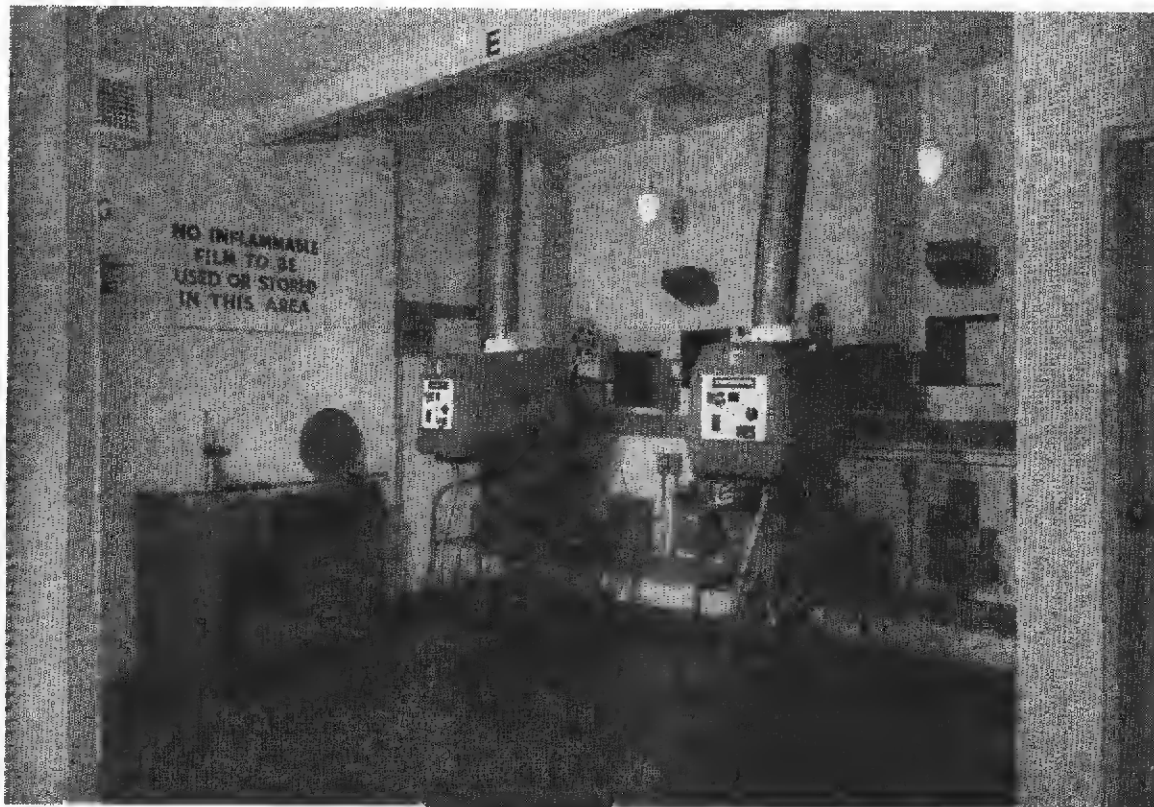


Fig. 18 — Six review theatre suite—16-mm projection bay

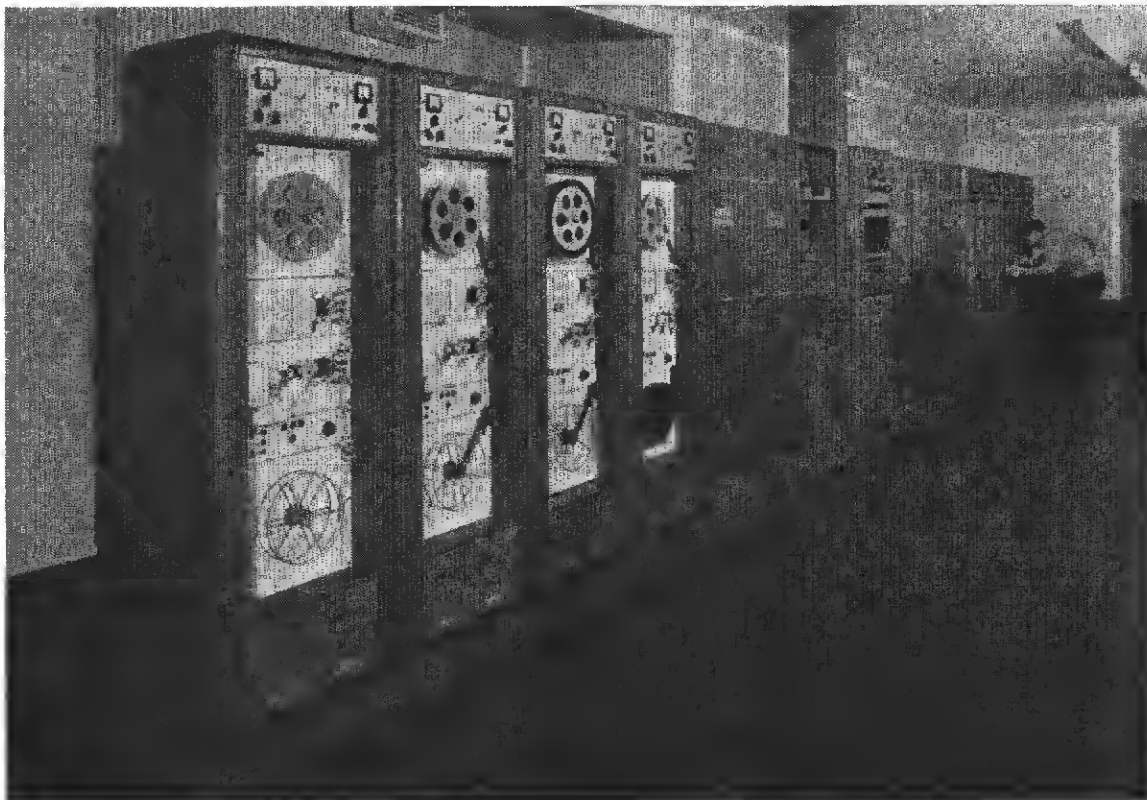


Fig. 19 — Six review theatre suite—sound reproducers and interlock section



Fig. 20 — Six review theatre suite—one of the theatres

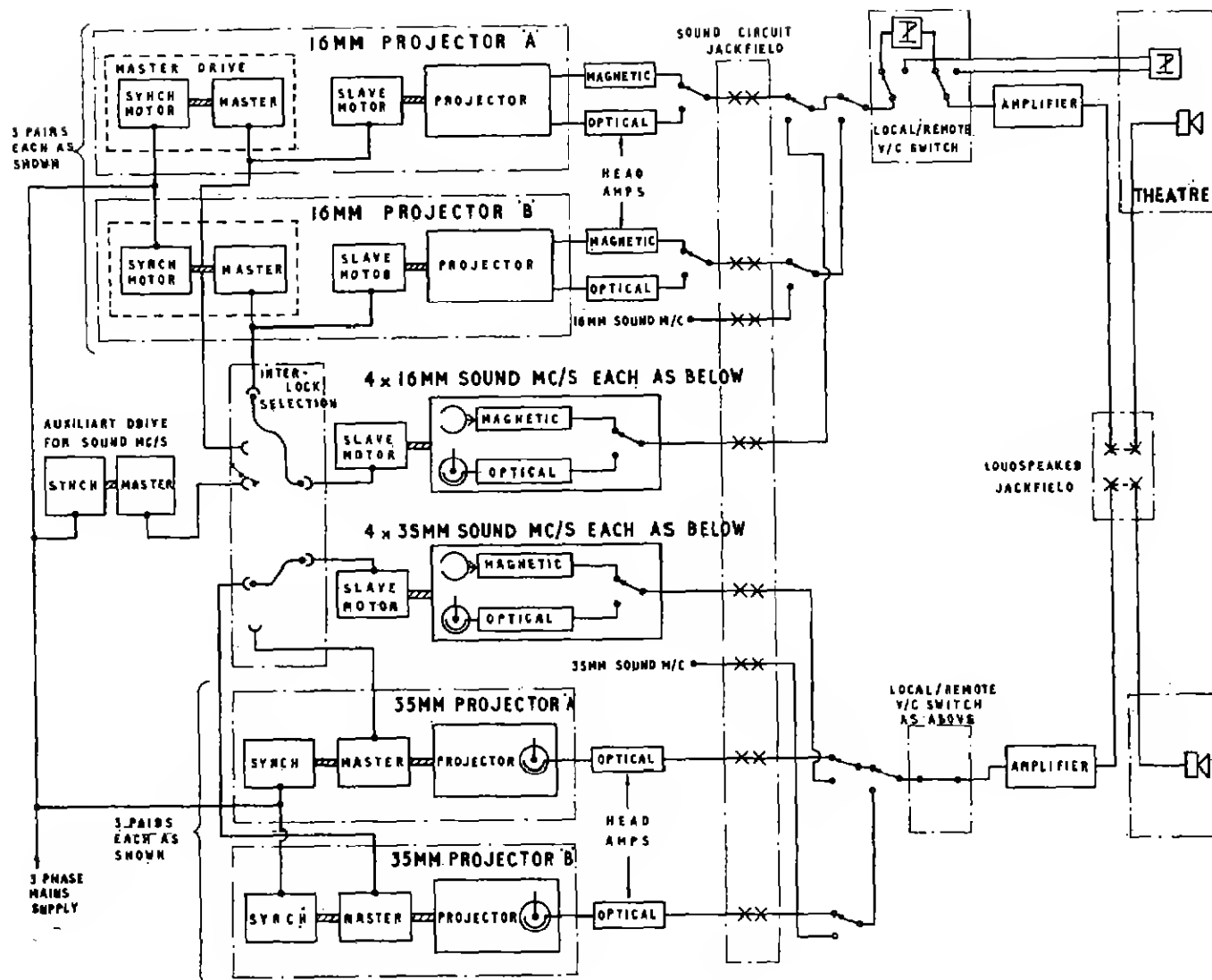


Fig. 21 — Review suite schematic

resemblance to a television image. Standardization on this type of illuminant also enables an accurate match to be obtained between 16-mm and 35-mm since arcs have been found necessary in any case for the 35-mm machines. It is possible that the arc illuminants will be replaced eventually by xenon-type lamps since service trials in the dubbing theatre (see Section 10) are showing that these can provide at least equal results with improved operational efficiency and cleanliness.

9.8 Theatres

Each theatre is identical (Fig. 20) and the equipment comprises a small, matt, non-perforated screen measuring approximately 3 ft 9 in. in width, a high-grade loudspeaker beneath the screen, a producer's desk with talkback, volume control and film frame indicator, and approximately twelve seats.

The overall size of the theatre (12 ft by 15 ft) and also the screen size have purposely been kept low to simulate television viewing conditions, and the loudspeaker and

acoustics are designed to provide television listening conditions. The screen illumination is standardized at 12-ft lamberts. This has been found in practice to be a good compromise for checking films for television purposes and it is interesting to note that the S.M.P.T.E. of America recommends an identical figure.

A disk playback turntable is provided on the control desk in each theatre to facilitate selection of music to suit a particular film or film sequence.

10. Film Dubbing

10.1 General

The film dubbing operation is necessary in order to produce a single master sound track for the picture film from all the separate sound ingredients involved, i.e. dialogue recorded at the time of filming, commentary, effects from disk or film, and background and title music tracks. The dubbing operation involves projecting the picture, reproducing all the separate sounds in synchronism, mixing

these sounds in the correct proportions and at the correct time, and recording the final result on to one magnetic sound film, also in synchronism.

A dubbing theatre existed at Ealing Studios and the BBC has continued to use it largely unaltered. This has been necessary in order to meet the programme load consequent on moving all other operations to these premises. The theatre is not ideal for television work, however, and much of the equipment is obsolete. Plans are now being considered for improvements, but at the time of writing they have not been finalized. This description is, therefore, limited to the present system.

The main operational difficulty is that the theatre is designed for feature film production, where the finished product is destined for reproduction in a large auditorium. Sound mixing and control is, therefore, carried out in a

comparatively large theatre. Sound mixing for television should obviously be carried out under conditions approximating to an average living room. In order partially to overcome this difficulty a standard BBC loudspeaker has been installed which can be moved close to the mixer desk together with acoustic screens. The two other BBC dubbing theatres, at Alexandra Palace and Lime Grove, were specially designed and in these sound mixing takes place under the correct conditions.

Another problem at Ealing was that a large proportion of television film dubbing involved the addition of a commentary. This requires a well-treated commentary studio of adequate size, facing the screen and this facility did not exist.

However, a commentary room has been added and other minor modifications have been carried out to the

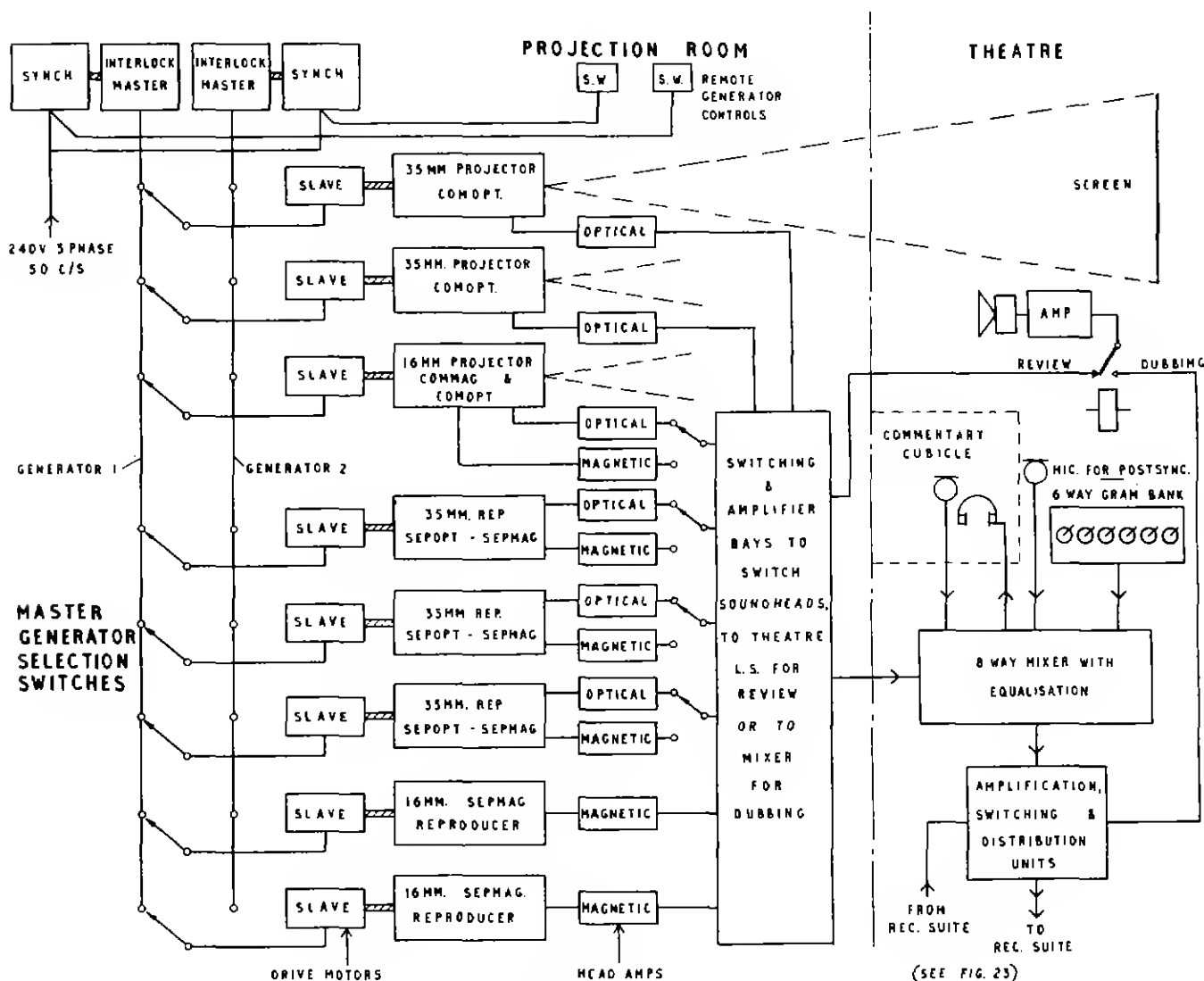


Fig. 22 — Dubbing suite schematic



Fig. 23 — Film dubbing theatre—showing a dubbing session in progress

areas and equipment resulting in a tolerably satisfactory suite able to carry a fair proportion of the television film dubbing load.

10.2 Details of Installation

The equipment schematic is shown in Fig. 22.

A commentary studio has been installed in the only space available. This is very small but it is tolerable acoustically and reasonably sound-proof. Six gramophone playback turntables have been installed alongside the mixer, as shown in Fig. 23. These are required for the playback of non-synchronous sounds, i.e. music, laughter, machine noises, etc., etc.

The projection equipment consists of the two original 35-mm projectors, to which have been added a 16-mm Bell and Howell 609 projector arranged for COMOPT or COMMAG reproduction.

Xenon-type illuminants (Fig. 24) have been added to all the projectors in order to gain service experience of this type of lamp. Results to date have been extremely en-

couraging. 2-kW Mazda, xenon lamps are used operating at 55A. They are installed in special lamphouses equipped with 12-in. mirrors and the special control and pulse-strike unit is mounted at the rear. The illuminants are set up to provide a screen illumination of 12-ft lamberts.

The sound reproducers consist of three 35-mm machines each arranged for SEPOPT and SEPMAG reproduction, and two 16-mm machines designed for SEPMAG reproduction only. All the equipment is fitted with interlock slave motors which can be coupled as required to two master interlock distributors (see Fig. 22).

The sound mixing desk is a standard film-studio-type mixer capable of dealing with eight sources and fitted with comprehensive equalizing facilities.

The output of the dubbing theatre is fed to the film recording suite situated below the theatre and described in Section 11.

An interesting feature of the dubbing theatre installation, not shown in Fig. 23, is a new BBC film-footage indicator

which has been developed for use where a large display at more than one position is required. This employs three stacks of digits, each 0-9, engraved on perspex illuminated by the internal reflection method. Each sheet of perspex, thirty in all, is lit by separate lamps which are operated by a standard uni-selector sequence switching unit. This switch unit is impulsed by a contactor on the appropriate projector. Any number of display units can be coupled to the master switch unit and it is hoped that the reliability and flexibility of the whole system will be very high.

11. Film Recording Suite

This central suite is at present being replanned as shown in Fig. 25. The present complement of machines is two 35-mm recorders, but it is hoped to provide eventually a total of three 35-mm magnetic channels and two 16-mm channels. These will all be equipped with dual interlock and synchronous drives and be suitable for dubbing or studio re-

cording purposes as the load demands vary. The number of machines has been designed to enable each equipment to be withdrawn from service for maintenance purposes on a regular schedule. The planning also provides for synchronous playback from any machine to any studio if required.

12. Power Supplies

The studio lighting system at Ealing operates from a 3-wire 230-V/110-V d.c. system. This is supplied from two diesel generators each of 800-kW capacity. Normally only one of these machines is running, but the second can be added in parallel if the load necessitates it. A.c. generation plant consists of one 150-kVA diesel-alternator set and a 120-kVA d.c.-a.c. motor-alternator set, which can be supplied from either of the diesel-driven d.c. machines. Normally all a.c. circuits are fed from the public mains, but switching is provided to enable sections, or all, of the a.c. load to be

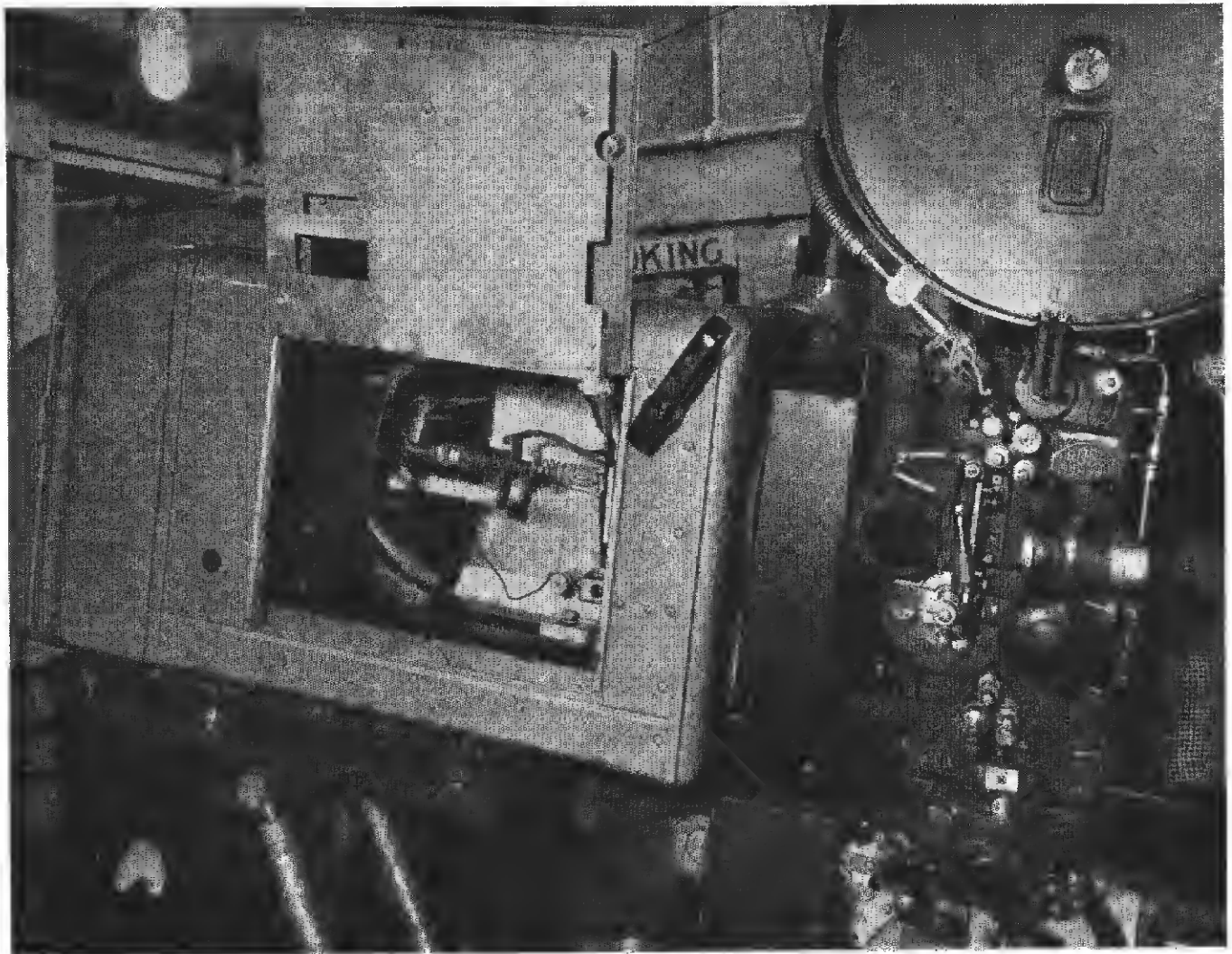


Fig. 24 — Film dubbing theatre—35-mm projector showing xenon illuminant

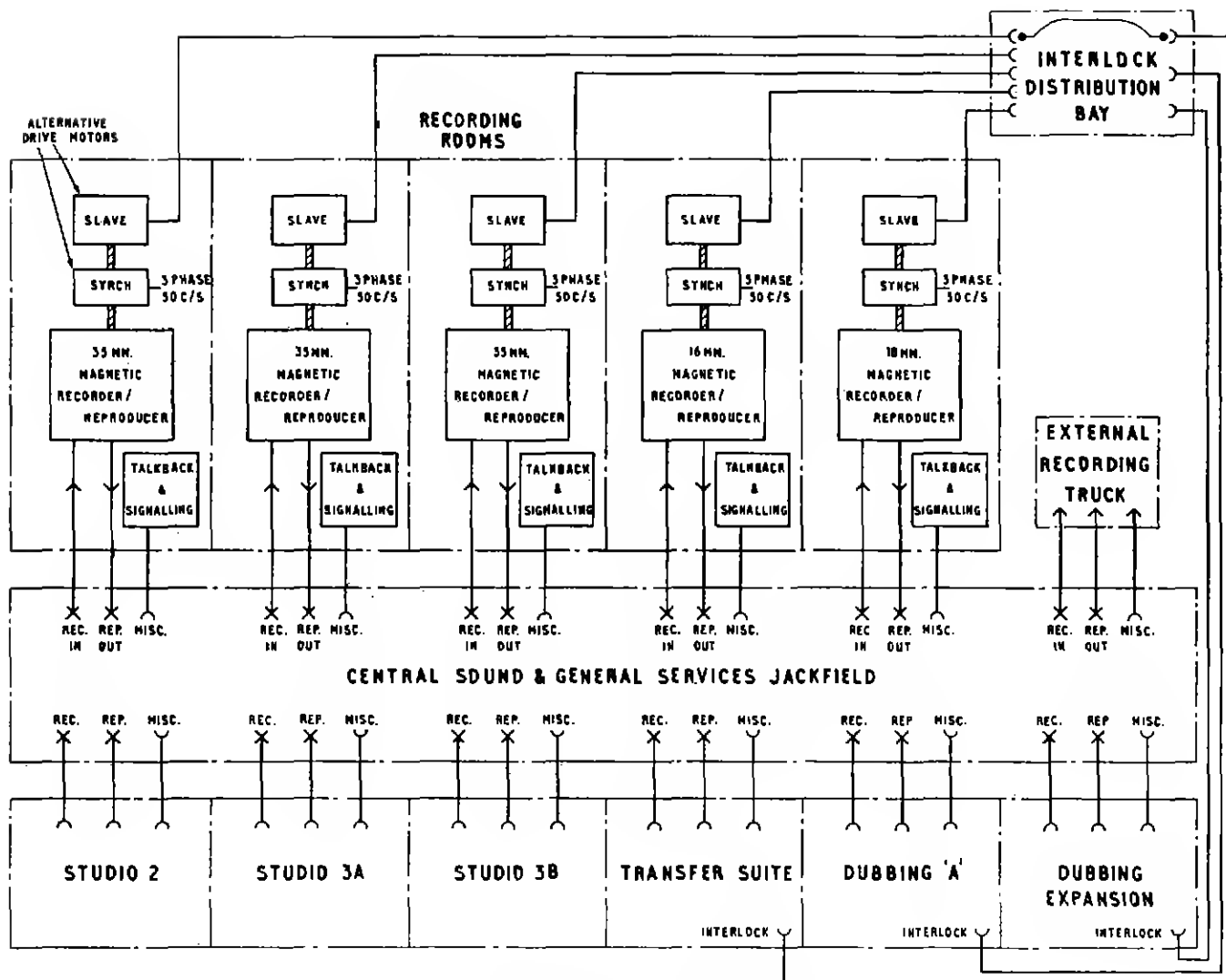


Fig. 25 — Recording suite schematic

connected to the above plant. This is mainly to cover a mains failure, but is also useful in loading up the diesels and restricting the load on the mains.

A.c. voltage regulating equipment is installed for essential supplies to sound equipment in the dubbing, main recording, and transfer suites.

13. Film Maintenance

The BBC Film Production organization in London, including subsidiary units at Lime Grove and Alexandra Palace, comprises the following equipment:

- Three dubbing theatres.
- Twelve review theatres.
- Two sound transfer suites.
- Three film stages.
- Approximately one hundred film cameras.
- Thirty mobile sound equipments.
- Approximately fifty fully equipped cutting rooms.

The maintenance of all this equipment is the responsibility of the Film Maintenance Section of the Television Operations and Maintenance Department.

A comprehensive suite of rooms is allocated at Ealing to this section as shown in Fig. 1. These comprise areas for camera maintenance (Fig. 26), general mechanical maintenance, and electronic workshops. Equipment storage areas are also provided, and a number of spare equipments are kept ready for service use.

14. Film Catalogue Section

14.1 Methods

The Film Library is based at Ealing although a considerable proportion of the film material itself still remains at Lime Grove, since there is a considerable vault capacity available at that centre.

A full description of the Film Library and its methods are contained in a paper⁽⁹⁾ by the BBC's Film Librarian

and reference should be made to this for further details. It is sufficient to say here that the catalogue section is housed in the West Lodge at Ealing, see Fig. 1. Every piece of film retained is recorded here under a quick reference system.

14.2 Film Vaults

A new block of film vaults has been constructed adjacent to the catalogue room and is illustrated in Fig. 27. This comprises forty film vaults, each vault being capable of storing approximately 500 000 ft of film.

The library cataloguing system files all film in numerical sequence as it arrives for storage whether it be 35-mm or 16-mm, or in 100-ft or 2 000-ft lengths. This necessitates a special vault racking system capable of taking any 16-mm or 35-mm tin size from 400 ft to 2 000 ft. This is shown in Fig. 28. To prevent any long-term effect on magnetic film non-magnetic material is used for racking although no evidence has been found on a short-term basis that ferrous materials cannot be used.

15. Conclusion

The acquisition of the Ealing premises and the provision of the facilities described have enabled the BBC Television Service to centralize its main film production activities and to provide even for expansion in the future.

Over a twelve-month period of operation between 1957 and 1958 film was produced for approximately 1 200 programmes, the average amount of screen time contributed to the television service, excluding feature films, etc., being approximately four hours a week. This includes studio and location sequences and miscellaneous external sources of film material requiring editing and dubbing, equivalent to the production of approximately 140 feature films in a year. This programme output included something like forty complete films each of approximately thirty minutes' duration.

Experience has shown that the segregation of this operation from the main 'live' television activities has undoubted advantages. Ideally, such a centre should be adjacent

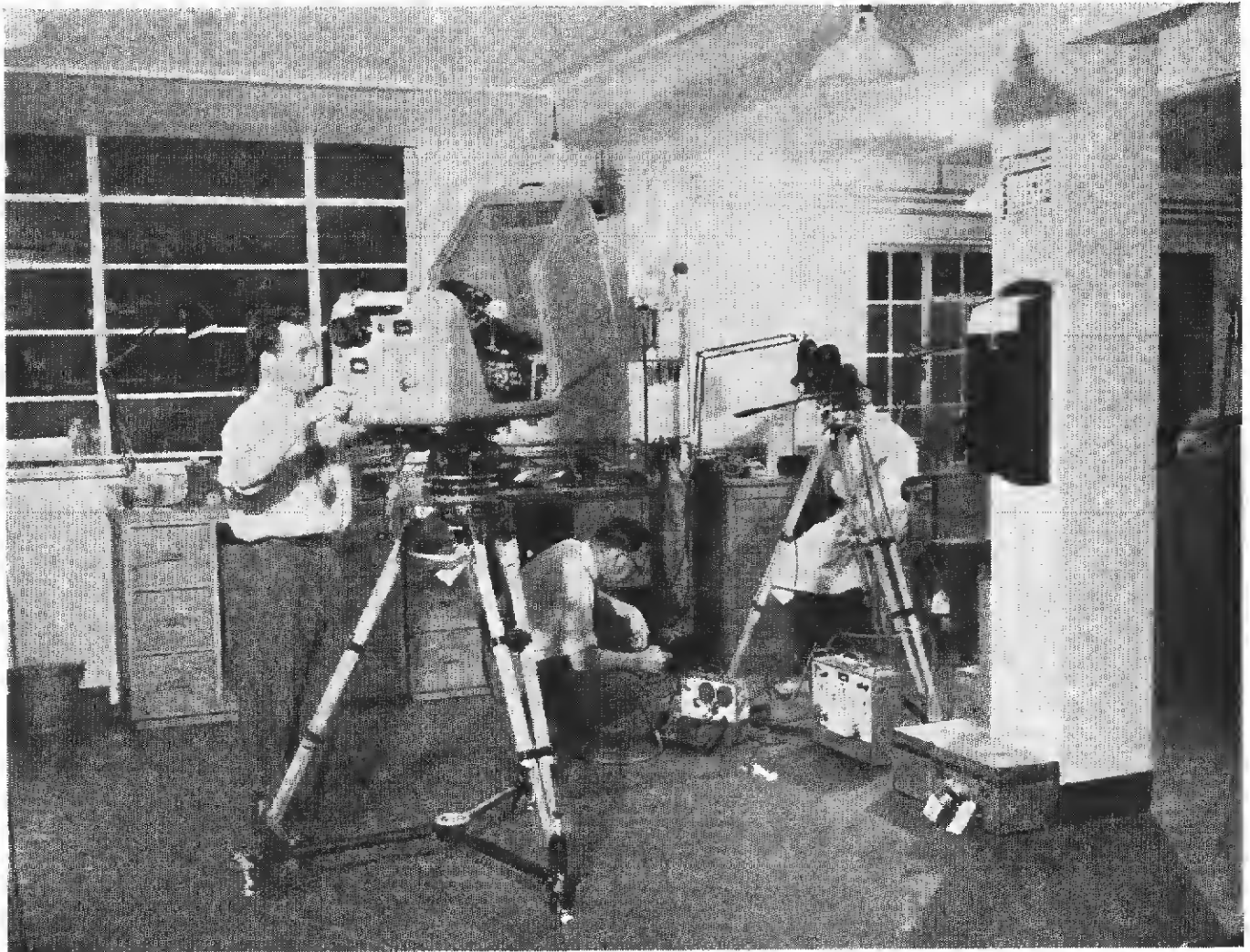


Fig. 26 — Film camera maintenance room

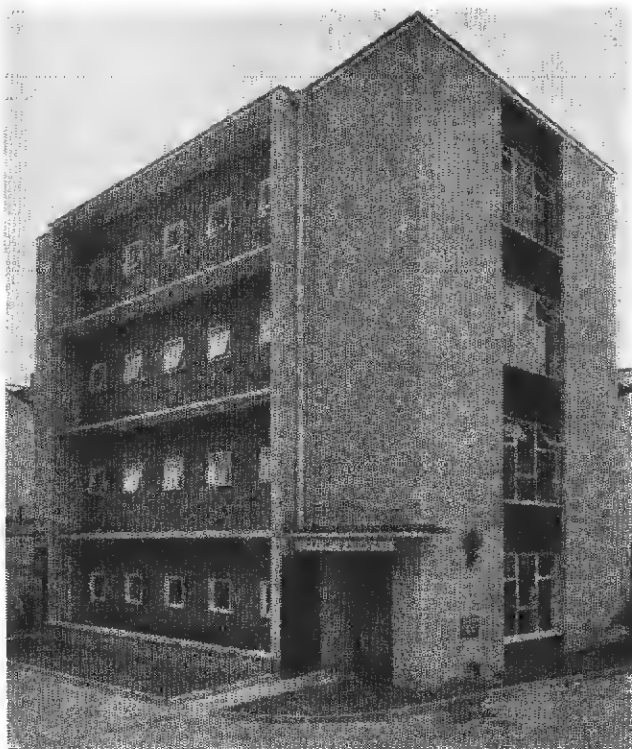


Fig. 27 — Film vault—exterior

to the main television centre to allow use to be made of the centralized film facilities by the highly topical television programme sections and to reduce travelling and film transit time. Even with Ealing in operation, it is still necessary to provide restricted film editing, review, and dubbing facilities at the television studio centre at Lime Grove and similar facilities may be required at Television Centre in due course. These are required for topical programmes on sport and current affairs for which film inserts are often being prepared right up to the time of transmission. Site problems, expediency, and economic considerations rarely allow the ideal to be achieved however, and the present arrangement is proving a reasonably satisfactory compromise.

The methods used at Ealing are a mixture of the traditional together with some new approaches to the problems. Here again economics, expediency, and availability of equipment are apt to influence procedure.

It is difficult to make firm predictions concerning future developments in television film production methods.

It is important in discussing future techniques to differentiate between the recording or pre-recording of television programmes produced in television studios and the pre-filming of programme material.

Electronic viewfinders for film cameras to enable production personnel to see on television monitors the subject matter being filmed have not proved very successful as an aid to film production either in the U.S.A. or in this country. They have not been tried at Ealing yet, however, and it is possible that further investigations and development of this technique may prove worth while.

'Electronic filming', using television cameras and production technique in conjunction with film telerecording, has also only met with moderate success in the industry so far, principally due to the difficulties of achieving adequate film quality.

Magnetic video recording provides improved television recording quality and the system will obviously be used extensively by television networks for the pre-recording either of sections or of complete television productions. However, it is not so easy to visualize its use as a television programme material producing medium outside the television networks. The cost of equipping and staffing an existing film studio with television vision equipment and magnetic video apparatus is very considerable.

It may well be that the existing complement of film camera and sound recording equipment in the industry as a whole will continue to be used for some time yet for the production of television film material since no extra capital costs are involved. The technical quality of 35-mm film is very good, and editing and interchange between countries working on different television standards present no problems.

Film cameras are likely to be used to record outside programme material for some time to come, mainly for reasons of portability and cost.



Fig. 28 — Film vault—showing 35-mm/16-mm racking

An important development required in the television film field is the improvement of 16-mm technical standards, both as regards equipment and handling, to enable more use to be made of this gauge of film with its attendant economies.

16. Acknowledgments

Acknowledgment must be made first of all to our predecessors at Ealing—Ealing Films, Ltd. Their good planning over many years and the excellent co-operation at the time of take over considerably eased the problem of switching our television film production operations to this centre. The valuable assistance given by Mr Baynham Honri in this respect must be recorded.

Our appreciation of the contribution made by Ealing Films to the prestige of the British Film Industry is recorded in a plaque which has been placed at the entrance

to the Studios and mentions some of the famous films produced by this Company.

The conversion of the Studios to television film production represents a joint planning effort by the BBC Film, Operations and Maintenance, and Planning and Installation Departments. Acknowledgment is also due to the author's colleagues in these departments who have contributed to the design and planning programme. In particular John Byers of Film Department and Dennis Craven of Planning and Installation Department should be mentioned.

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APPENDIX

TERMINOLOGY

A. Sound Film

The various combinations and types of sound and picture films have increased steadily over the past few years and various methods of referring to these have grown up in the industry resulting in some confusion. 'Combined or married picture and sound film', 'unmarried optical sound', 'separate magnetic film' are but a few of the terms used.

In an effort to standardize and simplify such references the BBC recently introduced a code system. This is now in use throughout the television service and has also been accepted by the European Broadcasting Union for international exchange references. This code is used in this monograph and is as follows:

35-mm picture with combined optical sound track	35 COMOPT
35-mm picture with combined magnetic sound track	35 COMMAG
16-mm picture with combined optical sound track	16 COMOPT
16-mm picture with combined magnetic sound track	16 COMMAG
35-mm picture with one optical sound track on separate 35-mm film	35 SEPOPT
35-mm picture with one magnetic sound track on separate 35-mm film	35 SEPMAG
16-mm picture with one optical sound track on separate 16-mm film	16 SEPOPT
16-mm picture with one magnetic sound track on separate 16-mm film	16 SEPMAG
35-mm picture with two magnetic sound tracks on separate 35-mm film	35 SEPDUMAG
16-mm picture with two magnetic sound tracks on separate 16-mm film	16 SEPDUMAG
For three sound tracks replace DU by TRI	
For four sound tracks replace DU by QUAD	

16-mm picture with one magnetic sound track on separate 35-mm film	16/35 SEPMAG
16-mm picture with two magnetic sound tracks on separate 35-mm film	16/35 SEPDUMAG
For three sound tracks replace DU by TRI	
For four sound tracks replace DU by QUAD	
35-mm picture with sound track on magnetic tape	35/T SEPMAG
16-mm picture with sound track on magnetic tape	16/T SEPMAG
35-mm picture only	35 MUTE
16-mm picture only	16 MUTE

B. Projector and Sound Equipment Drive System

- (a) *Interlock*. This refers to a type of drive which enables two or more machines to be coupled together electrically so that they will run up from a standing start in synchronism and maintain this synchronism throughout the run. The system usually employed has a master distributor with 3-phase wound rotors and stators. Slave motors driving the actual machines are similarly designed. All stators are connected in parallel and all the rotors are similarly paralleled. When 240-V 3-phase is applied to the stators, out of balance currents will flow in the rotor circuits until all rotors are in similar stationary alignment. Rotation of the master distributor by a synchronous drive motor will then cause all machines to run up in lock and maintain synchronism with the mains supply.
- (b) *Synchronous*. The machine is driven by a synchronous 3-phase 240-V motor. This means that all machines similarly driven will run synchronously with the mains supply once they are up to speed. Run-up times will vary, however, according to the type and size of machine.

